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East-West Exchange

The East-West exchange agreement between the United States and the Soviet Union, which was signed 27 January, is the product of a protracted series of negotiations. The first steps toward the exchange were taken at the Geneva summit conference in 1955 with the consequence that a few technical teams were exchanged in 1956. Not much exchange could take place, however, so long as the Russians refused to meet the United States requirement that all foreigners entering this country, other than officials, had to be fingerprinted.

The way to a wider exchange was opened when, early last fall, Congress gave the Secretary of State the right to waive the fingerprinting requirements. Negotiations for exchange began last October, and agreement was reached in January.

The State Department negotiated not only with the Soviet Union, but also with private American groups who might or might not want to enter into the exchange program; the Russians had no comparable problem owing to the different relation of their citizens to their Government. It is to this difference that the remarkably specific terms of the agreement may be attributed. Thus, for example, the countries agreed to exchange eight medical delegations of five or six specialists in the fields of antibiotics, microbiology, physiology and pharmacology of the nervous system, and so on, for periods ranging from two to six weeks; to exchange a Soviet pianist and a violinist for two American vocalists; and to exchange 20 students in 1958 and 30 in 1959. The same pattern was followed in other exchanges: so many exhibits, films, and radio and television programs will be traded, and so many people will be exchanged in the fields of agriculture, industry, medicine, the arts, the sciences, education, and athletics (including chess).

Wide as this range of occupations is, it is not complete; for some American groups would not enter into any arrangement because of their reluctance to do anything that would "legitimatize" their Soviet counterparts by making it appear that they accepted them as their equals in democracy and freedom from Governmental control. Among those who took this stand were the American Legion, the Boy Scouts, newspaper reporters, labor unions, and chambers of commerce. This limitation on the exchange is not as great as it seems: anyone can make his own arrangements to visit the Soviet Union, and the State Department stands ready to facilitate exchange for any organized group that wishes it.

There is another respect in which the exchange is not as effective as it might ideally be: certain cities in each country are out-of-bounds for nationals of the other country. This kind of eye-for-an-eye diplomacy arose when the Russians closed certain cities to Americans and the State Department retaliated by closing "equivalent" cities to the Russians.

As long as this kind of restriction remains in force we may expect repetitions of incidents like that of last November when a Russian chess champion was prevented from accepting an invitation to take part in a tournament in Dallas.

If exchange is a good thing—and both countries think it is—then it ought to be carried out in full. Both countries ought to relax their restrictions on travel. But if this cannot be done, why should we not take unilateral action and extend to the Soviets the same travel opportunities that we extend to other foreigners? If we did this the Soviet Union would have the choice of either following suit or having to defend a logically indefensible position.—G. DuS.

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Synthesis in the Study of Nucleotides

Basic work on phosphorylation opens the way to an attack on nucleic acids and nucleotide coenzymes.

Alexander Todd

The term *nucleotide* requires definition, for, like many other terms, it is now used in a much broader sense than when it was first introduced. Originally it was applied only to the phosphate esters of certain N-glycosides of purine and pyrimidine bases (the nucleosides) obtained on hydrolyzing nucleic acids. Today it is applied generally and rather loosely to phosphates of N-glycosides of heterocyclic bases, and it includes not merely the simple nucleotides of the original definition but also the nucleic acids (polynucleotides) and such substances as nicotinamide nucleotide (5′-phosphate of the quaternary N-ribofuranosylnicotinamide), and adenosine triphosphate (ATP). The nucleotide coenzymes are, in general, characterized by the presence in them of at least one simple nucleotide residue and, although derivatives of riboflavin phosphate (FMN) are not glycosidic in nature, they are commonly listed among the nucleotides because of their close similarity to, and association with, true nucleotides.

In 1939 when I first began experiments in this field the fundamental substances of the group—the nucleosides obtained by hydrolyzing nucleic acids—had long been known and had been the subject of study by various workers. The early studies of Fischer had been followed by those of a few other investigators, among whom one thinks particularly of Levene. As a result it was established that the four nucleosides derived from ribonucleic acids were N-D-ribosides of adenine, guanine, uracil, and cytosine, respectively, but the size of the lactol ring in the sugar residue and the configuration at the glycosidic linkage were unknown while the point of attachment of the sugar residue in the purine nucleosides was still in dispute, although the spectroscopic evidence of Gulland and Holiday (*1*) indicated with a high degree of probability that it was N_9. Of the nucleosides from deoxyribonucleic acids, all that was known with any certainty was that they were 2-deoxy-D-ribosides of the bases adenine, guanine, thymine, and cytosine, and it was assumed that they were structurally analogous to the ribonucleosides.

The chemistry of the nucleotides—the phosphates of the nucleosides—was in a correspondingly primitive state. It may well be asked why the chemistry of these groups of compounds was not further advanced, particularly since we recognize today that they occupy a central place in the chemistry of the living cell. True, their full significance was for long unrecognized and emerged only slowly as biochemical research got into its stride, but I think a more important reason is to be found in the physical properties of compounds of the nucleotide group. As water-soluble polar compounds with no proper melting points, they were extremely difficult to handle by the classical techniques of organic chemistry and were accordingly very discouraging substances to early workers. It is surely no accident that the major advances in the field have coincided with the appearance of new experimental techniques such as paper and ion-exchange chromatography, paper electrophoresis and countercurrent distribution peculiarly appropriate to compounds of this group. Without them and without the availability of convenient and precise spectroscopic methods, I doubt whether our work would have been possible.

I decided that we should seek to clarify the nucleotide field beginning with the simplest units—the nucleosides. To do so we applied primarily the method of synthesis since the amount of preliminary information available from earlier work had at least given sufficient indication of the nature of the nucleosides to make such an attack appropriate. This phase of our work, although providing, I believe, an interesting example of the power of synthetic methods in structural work, would take an entire lecture to describe in itself, and I shall not, therefore, discuss it here. Suffice to say that this work led to the rigid establishment of the structure of the individual ribonucleosides as the 9-β-D-ribofuranosides of adenine and guanine and the 3-β-D-ribofuranosides of uracil and cytosine and to the total synthesis of all of them (*2*). The deoxyribonucleosides were similarly shown to be 9-β-2-deoxy-D-ribofuranosides in the case of the purine, and 3- β-2-deoxy-D-ribofuranosides in the pyrimidine members (*3*).

The difficulty of obtaining and of handling derivatives of 2-deoxy-D-ribose has hampered synthesis of the natural deoxyribonucleosides, but deoxyuridine has recently been synthesized (*4*) and it is likely that synthesis of the others will shortly follow. For reference the structural formulae of two typical nucleosides, the ribonucleoside adenosine (I) and

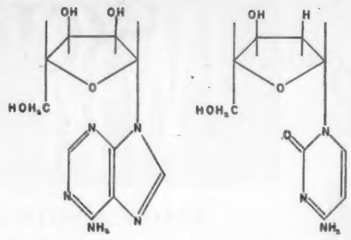
Sir Alexander Todd is professor of organic chemistry at Cambridge University, Cambridge, England. This article is based on the lecture he gave in Stockholm, Sweden, on 11 Dec. 1957, when he was awarded the Nobel prize in chemistry for 1957. It is published with the permission of the Nobel Foundation.

the deoxyribonucleoside deoxycytidine (II), are given in Fig. 1.

The simple nucleotides are phosphates of the nucleosides, the phosphate residue being attached to one or other of the hydroxyls in the sugar portion of the molecule. Phosphorylation of the nucleosides was thus a second essential phase in our studies. Although organic phosphates and polyphosphates are of widespread occurrence in living matter, relatively little attention had been paid in the past to their synthesis and still less to their chemical behavior. True, a number of organic phosphates had been prepared, usually by rather crude procedures not well suited to use with sensitive molecules, and we found it necessary to undertake a general study of phosphorylation in all its aspects so as to make available methods which might be satisfactory in dealing with the rather wide range of delicate structural features to be encountered in the nucleotide and nucleotide coenzyme field.

The most widely employed phosphorylating agent which emerged from these studies is dibenzyl phosphorochloridate $(C_6H_5CH_2O)_2POCl$ (*5*). This rather unstable substance may readily be prepared in solution from dibenzyl phosphite by chlorination either with chlorine itself or with N-chlorosuccinimide, and it reacts smoothly with alcohols in the presence of tertiary bases to yield alkyl dibenzyl phosphates from which the protecting groups may be removed by a variety of methods. Monodebenzylation may be effected by treatment with strong tertiary bases (*6*), by anionic fission (*7*), or by partial hydrogenation; complete debenzylation can be brought about by, for example, hydrolysis, catalytic hydrogenolysis, or ammonolysis.

Although dibenzyl phosphorochloridate has been the most generally used reagent for the phosphorylation of alcohols, other methods have been developed by us which are also effective and find uses in particular cases. These include phosphorylation with tetraesters of pyrophosphoric acid (*8*), with mixed anhydrides of diesters of phosphoric acid with stronger acids (for example, sulfonic acids) (*9*), the reaction of dialkyl phosphites with polyhalogen compounds in presence of a base and the substance to be phosphorylated (*10*), and the important phosphite route in which an alcohol is converted first to an alkyl benzyl phosphite by treatment with the mixed anhydride of benzyl phosphorous acid and diphenyl phosphoric acid, the phosphite then being converted to phosphate either via the phosphorochloridate or by direct oxidation (*11*).



I II

Fig. 1. Structural formulae of two typical nucleosides, ribonucleoside adenosine (I) and the deoxyribonucleoside deoxycytidine (II).

As a result of these basic studies on phosphorylation we were able not only to synthesize all the theoretically possible simple nucleotides derived from the natural ribonucleosides and deoxyribonucleosides but to open the way to an attack on the more complex problems presented by the nucleic acids and the nucleotide coenzymes (*2, 12*). Since these represent two distinct though interrelated aspects of nucleotide chemistry, it will be convenient to treat them separately in this discussion.

Nucleic Acids

It is now well over eighty years since the first nucleic acid was isolated by Miescher from pus cells. Since that time it has become clear that they are essential constituents of all living cells, commonly occurring in association with proteins in the so-called nucleoproteins among which are numbered many viruses and enzymes, and that they are among the most complex of all the substances occurring in living matter. Over the years many early misconceptions have been removed, and it is now recognized that the number of individual nucleic acids is large and that all so far discovered belong to one or the other of two types—the ribonucleic acids and the deoxyribonucleic acids, the former yielding on hydrolysis D-ribose and the latter 2-deoxy-D-ribose.

The general nature of the nucleic acids is indicated by their behavior on hydrolytic breakdown, when they yield simple nucleotides which can be hydrolyzed further to give nucleosides and phosphoric acid in equimolecular proportions. The nucleic acids are thus to be regarded as polynucleotides in which, as Levene and Simms (*13*) showed, individual nucleotides are linked one to the other through phosphodiester groups; pyrophosphate and ether linkages are absent. Although the nucleic acid molecules are very large—molecular weights may be as high as several million in some cases—the number of individual nucleosides involved in them is surprisingly small. Indeed, from the ribonucleic acids in general four nucleosides are obtained—adenosine, guanosine, uridine, and cytidine—although recently there have been reports of trace amounts of one or two other nucleosides in certain individual acids. Deoxyribonucleic acids yield four main nucleosides—deoxyadenosine, deoxyguanosine, deoxycytidine, and thymidine—but at least two others, 5-methyl- and 5-hydroxymethyldeoxycytidine, are also of fairly frequent occurrence. Knowing from our intial studies the complete structure of the nucleosides, the outstanding problem in nucleic acid chemistry was the precise location of the internucleotidic linkage (*14*).

Until 1949 it was believed that alkaline hydrolysis of ribonucleic acids yielded only four simple nucleotides, which, mainly on evidence adduced by Levene, some of which we now know to have been of doubtful validity, were regarded as the 3′-phosphates of the respective nucleosides. On this basis it was not at all easy to provide a rational polynucleotide structure. In 1949, however, Cohn began to apply the technique of ion-exchange chromatography to alkaline hydrolyzates of ribonucleic acids, and he showed that they contained not four, but eight, nucleotides made up of four pairs of isomeric nucleotides, each pair derived from one of the four nucleosides; these pairs he described originally as the *a* and *b* nucleotides—that is, there were adenylic acid *a* and adenylic acid *b*, uridylic acid *a* and uridylic acid *b*, and so forth. By a fortunate coincidence this work was car-

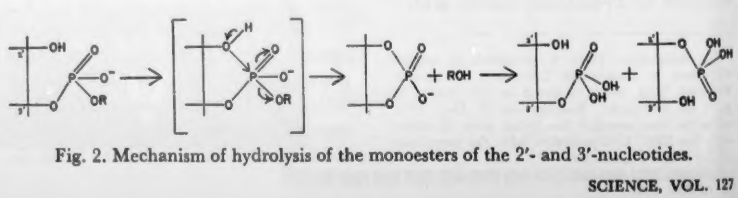


Fig. 2. Mechanism of hydrolysis of the monoesters of the 2′- and 3′-nucleotides.

ried out at much the same time as we were carrying out the synthesis of the individual ribonucleotides, and it soon became clear that the *a* and *b* nucleotides were, in fact, the 2′- and 3′-phosphates of the respective nucleosides, although at the time we were unable to say with any certainty which was the 2′- and which the 3′-derivative. It will simplify our story if I say here that we were able later to establish firmly that Cohn's *a* nucleotides are the 2′-phosphates and his *b* nucleotides the 3′-phosphates of the respective nucleosides, but the reasons for our inability to differentiate them immediately are at once interesting and of profound significance for the understanding of nucleic acid structure and behavior, and have had wide repercussions in other areas of phosphate chemistry.

Our early attempts to prepare 2′- or 3′-nucleotides individually by phosphorylation of ribonucleoside derivatives failed partly because of difficulties in group protection but more particularly because of phosphoryl migration which always led to mixtures of the 2′- and 3-′isomers being obtained. Although stable in alkaline solution, either pure isomer is converted in acid solution by phosphoryl migration into an equilibrium mixture of the two, probably by way of a cyclic intermediate. Even more interesting is the behavior of monoesters of the 2′- and 3′-nucleotides. Normally phosphodiesters are remarkably stable toward alkali, but these esters are not. They hydrolyze readily in dilute aqueous alkali, yielding always a mixture of both isomeric nucleotides. The mechanism of this hydrolysis is, we believe, that pictured in Fig. 2 (only the 2′- and 3′-positions of the sugar residue are shown since the rest of the molecule is irrelevant to our argument).

It should be noted that the over-all reaction as indicated in Fig. 2 is a two-stage process; the first is formation of the cyclic phosphate with simultaneous expulsion of the group *R*, and the second the hydrolysis of the cyclic phosphate in either of two ways to give a mixture of nucleotides. It may also be mentioned that the cyclic phosphates have indeed been isolated as first products in the above hydrolysis and have also been prepared synthetically and shown to have the expected properties. This interesting behavior is, of course, not confined to the esters of the 2′- and 3′-nucleotides; it is indeed observed in all phosphodiesters where a hydroxyl occurs *cis* to the phosphate group on the

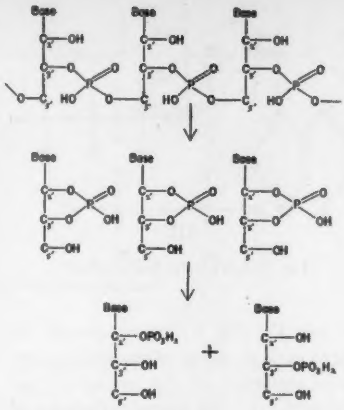


Fig. 3. Hydrolytic breakdown of a ribonucleic acid with alkali.

vicinal carbon atom. An analogous behavior is shown, for example, by the monoesters of the glycerophosphoric acids. But it is of particular relevance to an understanding of nucleic acid behavior, for, if in the abbreviated formula of the nucleotide ester used in Fig. 2 the group *R* represents a polynucleotide chain, then the analogy with ribonucleic acid itself becomes clear. The scheme shown in Fig. 3 (in which the expression "Base—$C_{2'}$—$C_{3'}$—$C_{5'}$" is used to represent a ribonucleoside residue, 2′, 3′, and 5′ being the only possible points of attachment of phosphate) represents our view of the hydrolytic breakdown of a ribonucleic acid with alkali to give exclusively a mixture of the 2′- and 3′-phosphates of the ribonucleosides.

This theory of hydrolytic breakdown provides a simple explanation for the fact that ribonucleic acids yield simple nucleotides with alkali, no larger fragments being obtained, and also explains why, in contradistinction to ribonucleic acids, the deoxyribonucleic acids are alkali stable; lacking the vicinal hydroxyl group on C_2, the latter compounds show the normal stability of simple diesters of phosphoric acid. On these considerations, coupled with certain other evidence, Brown and I (*15*) postulated both types of nucleic acids as 3′:5′-linked polynucleotides. All subsequent work has confirmed this view of their structure and it is today generally accepted. The main evidence as now available may be briefly summarized for the two types of nucleic acid as follows.

Ribonucleic acids. Ribonucleic acids are unstable to alkali, yielding simple nucleotides; the cyclic phosphates postulated as intermediates have been in fact isolated. Enzymic hydrolysis (snake venom) shows the participation of $C_{5'}$ in the internucleotidic linkage. Studies of the action of ribonuclease and spleen nuclease on the cyclic 2′:3′-phosphates of nucleosides and on esters of 2′- and 3′-nucleotides show that only $C_{3'}$ is involved in the internucleotidic linkage. This is supported also by the behavior of synthetic dinucleoside phosphates (5′:5′, 2′:5′ and 3′:5′) toward chemical and enzymic hydrolysis.

Deoxyribonucleic acids. Deoxyribonucleic acids are stable to alkali; hydrolysis by appropriate enzymes can yield 3′- or 5′-nucleotides. Acid hydrolysis yields *inter alia* pyrimidine nucleoside 3′:5′-diphosphates. Moreover, dithymidine-3′:5′-dinucleotide occurs in digests of deoxyribonucleic acids and has been identified with a synthetic specimen (*16*).

It seems probable that the nucleic acids are linear rather than branched polyesters. This is certainly true of isolated deoxyribonucleic acids, since only branching on phosphorus is theoretically possible, and such branching points involving phosphotriester linkages would not have the necessary alkali stability. In the case of ribonucleic acids we have shown that branching on phosphorus is incompatible with stability requirements, but chain branching on $C_{2'}$ of the sugar residue of the nucleoside remains a theoretical possibility although no experimental evidence for its occurrence in any ribonucleic acid has yet been adduced.

Since the essential difference between individual nucleic acids must reside in the different sequence of nucleoside residues in them, methods for sequence determination are clearly of importance for further work. Studies on this problem have not been encouraged by the fact that, as yet, no truly homogeneous nucleic acid preparations have been made, but we have devised one method for stepwise degradation which has been shown to be effective for oligonucleotides (*17*) and may be capable of application to ribonucleic acids themselves.

As yet chemical synthesis in the polynucleotide field is in its infancy. Unambiguous syntheses of dinucleoside phosphates and of at least one dinucleotide have been realized, and a start has been made using, essentially, mixed anhydride methods to develop polycondensation methods suitable for rapid polynucleotide synthesis. The increased activity now evident in this field, both in my own laboratories and in those of my

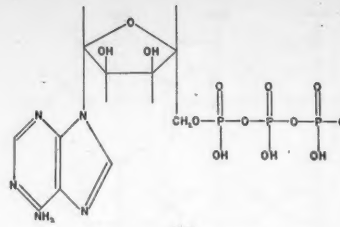
former students and colleagues, encourages me to predict rapid advances in this important aspect of nucleic acid research.

Space does not permit me to pursue this topic further and to trace how the chemical information discussed above has been combined with the results of x-ray and other studies to build up current views on the macromolecular structure of the deoxyribonucleic acids. Suffice to say that the double helical structure of the DNA molecule adumbrated first by Watson and Crick (*18*) on these foundations bids fair to open a new era in molecular biology. For it offers clues to the significance of nucleic acids in the transmission of hereditary characteristics and, taken in conjunction with our greater understanding of the properties and reactions of organic phosphates, it permits an approach to a closer understanding of the role of nucleic acid in cellular processes.

Nucleotide Coenzymes

The term *nucleotide coenzyme* is applied to a large and growing group of substances which are vital components of many enzyme systems involved in metabolic processes (*19*). These substances function in association with specific proteins or apoenzymes, the complete enzyme system being made up of the combination apoenzyme + coenzyme (von Euler). Historically, the first member of the group is cozymase or diphosphopyridine nucleotide (DPN) whose existence was recognized in 1906 by Harden and Young, although it was not in fact isolated in a pure state until 1936 (von Euler and Schlenk); it functions as coenzyme in a group of oxidation-reduction enzymes belonging to the pyridinoprotein group. Other examples are flavinadenine dinucleotide (FAD), found in many flavoproteins, adenosine triphosphate (ATP), acting as a cophosphorylase and also as a provider of the energy used in muscular contraction, and many others. All known members of the group belong to one or other of two types: (i) monoesters of polyphosphoric acids in which the esterifying group is a nucleoside derivative or (ii) unsymmetrical P^1P^2-diesters of pyrophosphoric acid in which at least one of the esterifying groups is a nucleoside derivative. Adenosine triphosphate (III) (Fig. 4) is an example of type i and cozymase or DPN (IV) (Fig. 5) of type ii.

An examination of structures III (Fig. 4) and IV (Fig. 5) at once reveals the three basic problems of nucleotide coenzyme synthesis: (i) the synthesis of nucleosides, (ii) the phosphorylation and polyphosphorylation of nucleosides, and (iii) the linkage of dissimilar molecules one to another by pyrophosphate residues. Of these problems, solutions to i and to the simple phosphorylation part of ii were available to us from the work I have already described. Here I shall discuss only the synthesis of polyphosphates and of unsymmetrical diesters of pyrophosphoric acid leading to actual coenzyme synthesis.



III

Fig. 4. Adenosine triphosphate.

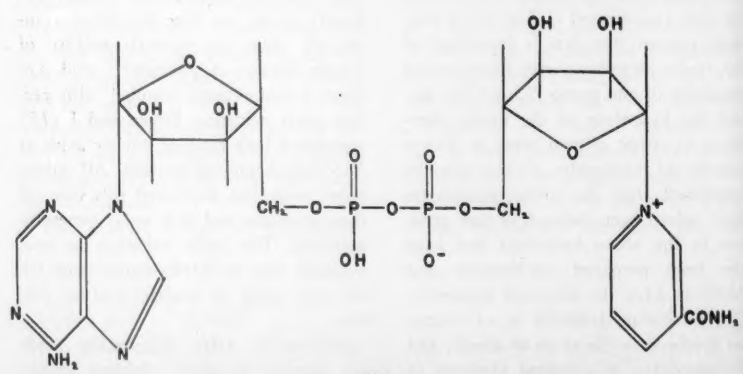
Starting from our most frequently used phosphorylating agent, the simplest and most direct route to pyrophosphates is the reaction between dibenzyl phosphorochloridate and the salt of a phosphodiester. With the variety of procedures open to us for partial or complete removal of benzyl groups, the scheme shown schematically in Fig. 6 can give not only monoesters of phosphoric and pyrophosphoric acids but also, by simple extension, either mono- or diesters of polyphosphoric acids in general.

This simple method of polyphosphate synthesis was used by us in the first total synthesis of adenosine-5′-pyrophosphate (ADP) and adenosine-5′-triphosphate (ATP) (*20*). The yields obtained in these early syntheses were usually poor for reasons which shortly became apparent to us as efforts to discover other and better procedures increased our knowledge of the properties and reactions of esters of pyrophosphoric acid.

Fully esterified pyrophosphates are very labile substances. Not only do they phosphorylate amines and alcohols but they readily undergo exchange reactions with other anions. For example, in presence of a base, tetraphenyl pyrophosphate reacts with dibenzyl phosphoric acid very rapidly even at 0°C to yield tetrabenzyl pyrophosphate and diphenyl phosphoric acid (*21*); this reaction is clearly a two-stage nucleophilic substitution, the first stage being formation of the unsymmetrical ester P^1-diphenyl P^2-dibenzyl pyrophosphate. The reaction appears to be a general one for pyrophosphates and for mixed anhydrides of phosphoric with other acids. In its most simplified form we may say that if two acids A and B form an anhydride AB, then if AB is brought into contact with the anion of an acid C, then if A is stronger (that is, has a more stable anion) than B, and C is weaker than A, we will have the reaction

$$AB + C \rightarrow BC + A.$$

It is this reaction that is primarily responsible for the low yields obtained in the ADP and ATP syntheses just mentioned, for the initial products of reaction are fully esterified polyphosphates and as such they rapidly undergo exchange reactions leading to reduced yields and to complex and difficultly separable mixtures. This tendency to undergo exchange reactions is less evident in the partially esterified polyphosphates (which are correspondingly less effective phosphorylating agents) and the phosphorochloridate method of poly-



IV

Fig. 5. Cozymase or diphosphopyridine nucleotide.

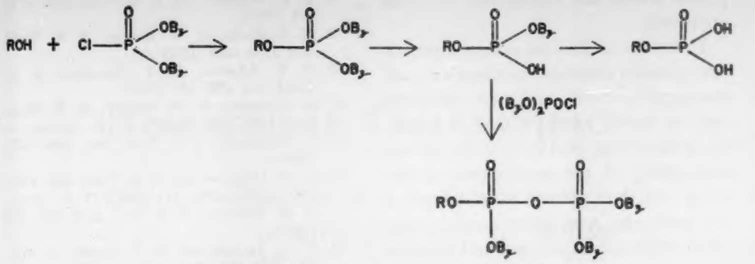


Fig. 6. Method of polyphosphate synthesis.

phosphate synthesis can be considerably improved if partially esterified phosphates are employed as starting materials. By this type of procedure we were able to effect total syntheses of the coenzymes flavinadenine dinucleotide (FAD) (*22*), uridine-diphosphate-glucose (UDPG) (*23*), and uridine-diphosphate-galactose (UDPGal) (*22*) as well as to provide much improved syntheses of the nucleoside-5′-polyphosphates.

The exchange reaction of polyphosphates which I have mentioned above is of particular interest because I have no doubt that it represents the main reaction employed in nature for polyphosphate synthesis. Numerous examples could be given but one will suffice. The enzymic synthesis of FAD from riboflavin phosphate and ATP described by Kornberg (*24*) is clearly a reaction of this type. It is interesting to note that in such cases nature appears to use mono-esterified polyphosphates whereas in the laboratory analogous reactions seem to occur readily only with fully esterified compounds. Presumably the protein component of the enzyme involved in the biological reaction produces an effect on the polyphosphates akin to that brought about by esterification. This labilizing effect of the enzyme protein may well be analogous to the labilization of the terminal phosphate residue of ATP which we have found can be achieved by allowing it to form an inclusion compound with β-cyclodextrin (*25*) and if so it suggests a new approach to some of the problems of enzyme action and specificity. In the laboratory the exchange reaction, in which fully esterified pyrophosphates are used, has not proved very useful for coenzyme synthesis since the extreme lability of the initially formed products makes the reaction too difficult to control.

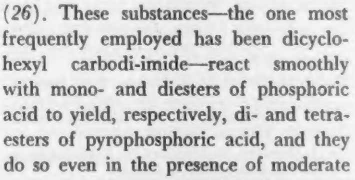
Quite apart from difficulties caused by the occurrence of exchange reactions, the phosphorochloridate route has also the disadvantage that, where nucleoside phosphorochloridates are employed, protection of the sugar hydroxyl groups by acylation or alkylation is necessary and, moreover, nonhydroxylic solvents must be used since phosphorochloridates react very readily with alcohols and with water. We have therefore devoted a good deal of effort to developing reagents for synthesizing pyrophosphates from phosphates without the need for protecting groups and which might be used even in presence of water since nucleotides are most easily handled in polar and particularly aqueous solvents. This has meant, in fact, the use of reagents which react with acids to form anhydrides more readily than they will react with water.

The first successful reagents of this type which we used were the dialkyl and diaryl carbodi-imides (RN=C=NR) (*26*). These substances—the one most frequently employed has been dicyclohexyl carbodi-imide—react smoothly with mono- and diesters of phosphoric acid to yield, respectively, di- and tetraesters of pyrophosphoric acid, and they do so even in the presence of moderate amounts of water provided that excess of the carbodi-imide is employed. The reaction goes well both in polar and nonpolar media and, although the mechanism has not been studied in detail, the first step is almost certainly an addition of phosphate to the carbodi-imide to give an adduct of type V (Fig. 7) which is then attacked by phosphate anion to give a pyrophosphate and the dialkyl urea.

The over-all reaction is very rapid and it has not been possible to halt it at the ψ-urea phosphate (V) stage; as a result, although the reaction is well nigh ideal for the production of symmetrical pyrophosphates, it is less satisfactory for unsymmetrical pyrophosphates of the nucleotide coenzyme type, since treatment of a mixture of two different phosphates with a carbodi-imide normally gives a mixture of all possible symmetrical and unsymmetrical pyrophosphates, the resolution of which into its components is often a matter of considerable difficulty. Despite this defect we have used the carbodi-imide reaction to synthesize a variety of nucleoside polyphosphates, uridine-diphosphate-glucose (UDPG) (*27*) and most recently to effect the total synthesis of cozymase (DPN) and of triphosphopyridine nucleotide (TPN) (*28*). It is of some interest to note that in the cozymase synthesis from nicotinamide nucleotide and adenosine-5′-phosphate in which di-*cyclo*hexyl carbodi-imide is used, very little di-(nicotinamide nucleoside-5′)-pyrophosphate was produced with a corresponding increase in the yield of the desired unsymmetrical product (DPN). Although the reason for this unexpectedly favorable result is not yet fully understood, it may be a characteristic of carbodi-imide reactions involving dipolar-ionic molecules, since a similar result has been obtained by Kennedy (*29*) in his preparation of cytidine-diphosphate-choline.

In addition to the carbodi-imides, several other reagents have been studied, which, although in general somewhat less reactive, function in the same way and are of practical value in certain cases. These reagents include the ketenimines, cyanamide, and the dialkylcyanamides. All these share with the carbodi-imides the disadvantages of producing mixtures of products when applied to unsymmetrical pyrophosphate synthesis; the dialkylcyanamides, however, are of particular value when it is desired to operate in aqueous solvents since they are considerably more resistant to hydrolysis than the carbodi-imides (*30*).

We have devoted much effort to devising other reagents and methods for pyrophosphate synthesis specifically designed to produce unsymmetrical esters and so to avoid the waste of materials and the inconvenience of the carbodi-imide method. Of these I shall mention only briefly two interesting methods which have emerged—the imidoyl phosphate method and the phosphoramidic acid method. The first of these employs as reagents imidoyl phosphates (for example, VI, Fig. 7) (*31*) for which sev-



V VI VII

Fig. 7. Structures V, VI, and VII.

eral preparative methods have been devised. These substances, which bear some formal resemblance to the enol-phosphates occurring in nature, react readily enough with phosphate anions to give pyrophosphates; unfortunately, however, in polar media some exchange between phosphate and imidoyl phosphate occurs and mixed products are again obtained. Similarly monoesters of phosphoramidic acid (for example, VII, Fig. 7), when protonated, react readily with phosphoric acids to yield pyrophosphates (*31*); they can be used to excellent effect in the synthesis of monesters of polyphosphoric acids (for example, ADP and ATP) but once again they yield mixtures of symmetrical and unsymmetrical esters when applied to the synthesis of diesters of pyrophosphoric acid.

In this field of nucleotide coenzyme synthesis, we are thus still seeking an ideal method for unsymmetrical pyrophosphate synthesis, although, having already developed five distinct types of synthetic method, we have reached a point at which the synthesis of any coenzyme molecule can be undertaken with reasonable certainty of success. Our practical interest in the field today lies very much in the methods of pyrophosphate formation and in the behavior of our pyrophosphates and mixed anhydride intermediates. For in the properties of such anhydrides lies the secret of many biological processes, and it is noteworthy that in our search for new methods we are in many ways coming closer and closer to the methods of nature—not only by working in aqueous media but also by using in some of our synthetic routes intermediates which bear a striking resemblance to some of the reactive phosphate derivatives such as enol-phosphates which are widespread in living organisms.

Today the nucleotides occupy a prominent place in chemical, biochemical, and biological research, and new vistas are opening before us which may in a relatively short time lead to a far deeper understanding of the mechanisms of the living cell than seemed possible only a few years ago. And this is surely a matter of profound importance to humanity in its ceaseless struggle against disease. We still have far to go, but if, in a small way, our chemical researches contribute to such an understanding then my colleagues and I are more than satisfied. I specifically include my colleagues in this statement, for the work I have attempted to review would not have been possible without the untiring efforts of a large number of brilliant and enthusiastic students and co-workers, among whom I would mention particularly Lythgoe, Baddiley, Atherton, Kenner, Michelson, Brown, Clark and Webb. It has been a privilege to be associated with them and to all of them I owe a deep debt of gratitude.

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Research in Outer Space

The basic objectives of a continuing program of satellite research are outlined.

Technical Panel on the Earth Satellite Program,
U.S. National Committee for the IGY,
National Academy of Sciences

The International Geophysical Year marks the beginning of man's exploration of outer space. There have been previous rocket firings into the fringes of the earth's atmosphere, but the expanded rocket-sounding program on an international scale and the advent of artificial earth satellites represent by far the largest steps taken towards the scientific exploration of outer space and the planets.

The interests of human progress and our national welfare now demand that a long-term program of space exploration be formulated and pursued by the United States with the utmost energy. Although there will inevitably be benefits of a very practical nature from such a program, the basic goal of this exploration must be the quest of knowledge about our solar system and the universe beyond.

The scientific program proposed here has been formulated with the following ideas in mind:

1) The technology of space flight will probably develop gradually. Therefore, the payloads and distances traveled will be relatively small at first, and the scientific experiments and observations will be correspondingly modest in the early stages.

2) The scientific program should be designed to give information at each stage which will help in the planning of later flights.

3) Manned space flight will occur in the course of the program, but before this occurs certain crucial experiments, which are aimed specifically at the design of a manned vehicle, must be performed.

4) In the quest for outer space we must not lose sight of the tremendous implications which the occupation of space will have for life on earth.

The experimental program proposed in this study represents concepts and views of many scientists but particularly those involved in the current IGY satellite effort. Of the latter group, the Technical Panel on the Earth Satellite Program of the U.S. National Committee for the International Geophysical Year and its three Working Groups have in one way or another contributed to the thoughts expressed in this article (*1*).

Sounding Rockets

Sounding rockets have provided so much information about the upper atmosphere and its effects on incoming radiation of various kinds that they will continue to be useful in this area. A continuing program in which such rockets are used should be aimed at determining the distribution, in the vertical, of such quantities as (i) atmospheric composition; (ii) atmospheric pressure, temperature, and density; (iii) winds in the upper atmosphere; (iv) atmospheric ionization; (v) the absorption of electromagnetic radiation penetrating the atmosphere and the intensities of sources of such radiation in the atmospheric layers; (vi) the absorption of cosmic ray or solar particles and the secondary effects of these particles; (vii) the geomagnetic field (also covered in the section on satellites); (viii) electric current systems in the atmosphere; (ix) experiments requiring recovery of packages.

With a sufficiently intense program, it will be possible to detect latitudinal, diurnal, and seasonal changes of these quantities, and also the ways in which they are modified during periods of solar activity and magnetic storms.

Until the techniques for the recovery of packages from a satellite have been worked out in more detail and demonstrated, there will be a class of experiments requiring the return of various kinds of samples for which the vertical rocket is required. These may involve (i) film samples: photographs, spectrographic data, cosmic ray packets, or data recordings where the quantity of information is too great to be telemetered back to the earth; (ii) biological samples.

Experiments for which sounding rockets will probably *not* be suitable in the future, with the availability of earth satellites of progressively larger payloads, are solar or astrophysical observations, particularly those in which time changes are sought. Clearly, a satellite vehicle is superior for such observations.

Earth Satellites

An earth satellite is considered, for these purposes, to be a vehicle which is on an orbit controlled primarily by the earth's gravity. Such a vehicle will orbit at a distance of something less than 1 million miles from the earth and with insufficient velocity to carry it further. Even when the technology of space flight has progressed far beyond the ability to put satellites on orbit, and vehicles are being directed on heliocentric and interplanetary missions, the earth satellite will surely continue to be a base for fruitful observations.

Fundamentally, a satellite well outside the earth's atmosphere can be used for observation of only three kinds of things—namely, photons, particles, and fields.

The photons, since they represent electromagnetic radiation, may range from x-radiation and ultraviolet radiation to

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The groups that have participated in the planning of the experimental program proposed in this study are as follows: *Technical Panel on the Earth Satellite Program*: R. W. Porter (chairman), G. M. Clemence, Michael Ference, Jr., Joseph Kaplan, Homer E. Newell, Jr., Hugh Odishaw, W. H. Pickering, J. G. Reid (secretary), A. H. Shapley, Athelstan F. Spilhaus, James A. Van Allen, Fred L. Whipple. *Working Group on Internal Instrumentation*: James A. Van Allen (chairman), Leroy R. Alldredge, Michael Ference, Jr., Herbert Friedman, William W. Kellogg, Hugh Odishaw, R. W. Porter, O. H. Schmitt, Lyman Spitzer, Jr. *Working Group on Tracking and Computation*: W. H. Pickering (chairman), G. M. Clemence, W. A. Heiskanen, J. T. Mengel, J. A. O'Keefe, J. E. Steakley, Fred L. Whipple. *Working Group on Satellite Ionospheric Measurements*: A. H. Shapley (chairman), W. Berning, George Grammer, C. Gordon Little, Wolfgang Pfister, J. C. Seddon, Ralph J. Slutz, G. W. Swenson, Jr., O. G. Villard, Jr., A. H. Waynick, H. W. Wells.

An earlier study of the panel in this area was prepared by R. W. Porter, J. A. Van Allen, H. E. Newell, W. W. Kellogg, and Lyman Spitzer, in January 1957. The present proposed program, based on the earlier report but considerably extending the scope of experimental possibilities, was prepared by W. W. Kellogg in collaboration with the Panel and the Working Group on Internal Instrumentation.

radio waves. In general, when one is dealing with photons coming from remote sources in the sun or beyond, the purpose of a satellite is to observe the wavelengths which do not penetrate the earth's atmosphere. This implies that the radiation of primary interest is at wavelengths below the ozone cutoff in the ultraviolet (about 0.32 microns) and at wavelengths above the ionospheric cutoff in the radio-wave region (about 30 meters, or 10 megacycles). Most of the radiation in between these limits penetrates the atmosphere and can therefore be observed on the ground or from balloons, except for some important, but limited, regions in the infrared where water vapor, carbon dioxide, and ozone cause absorption.

In addition to its use in observing these highly significant radiations from above, the satellite will be of great value in observing the earth, its changing cloud patterns, its infrared radiation, and so on.

The particles which can be observed from a satellite are solid meteoroids of various sizes and atomic nuclei with great energy emanating from the sun and from beyond (auroral particles and cosmic rays). Both types of particles are of great significance to the development of manned space vehicles, for the solid particles constitute a hazard to the vehicle, due to their ability to puncture its skin, and the atomic particles may be a hazard to the man inside.

The fields which are measurable from a satellite are the field of gravity and the magnetic field. Gravity is related to the masses and shapes of the earth and moon, and satellite observations promise to improve greatly the precision of our knowledge of these quantities. Magnetic field measurements not only tell about the magnetization of the earth and moon but also tell about the electric current systems in the vicinity of the earth.

Since a great deal has already been written about the uses of an artificial satellite, the experiments discussed below are presented in outline rather than in detail. First are those which could be carried out in Vanguard-type satellites—a statement based on the assumption that such satellites have a growth potential in payload to 50 or 75 pounds and that there will be a wider choice of orbits than there is under the IGY program. With larger payloads and more advanced techniques, more elaborate experiments could be performed—experiments which require stable platforms, high transmission power, large information bandwidth, recovery of packages, and so forth. Finally, there will be manned satellites.

Light-Weight-Satellite Experiments

Creation of visible objects. There are a number of reasons for wishing to have an easily visible satellite. In particular, precise determinations of orbit will probably be made optically, and it is clearly desirable to have a satellite which reflects or emits a considerable amount of light. At night, a flashing light with a brightness of 10^5 candle power or more would be just visible at a range of about 1000 miles, provided the duration of the flash was about 0.1 second or more. An alternative method for making the satellite visible is by using a large reflecting object such as a balloon or erectable corner reflector. Such an object, to be seen optically or visually, must be near the twilight zone of the earth, so that the observer can see the sunlit reflector against a darkened sky. Under such conditions a 100-square-foot diffuse reflector appears like a first-magnitude star at about 200 miles (if the angle between the sun and the observer is just right) and can still just be seen by the naked eye at a range of about 2000 miles. Naturally, with telescopes, one can do much better, but one must then know ahead of time where to look for the satellite.

With the sort of precise determinations of orbit which can be obtained with optical tracking, it is possible to do a number of important things. (i) Air drag at high altitudes, from which atmospheric density can be derived, can be determined. A possible complication here is the effect of an electrostatic charge on the satellite and the interactions between this charge, the ions present in the ionosphere, and the earth's magnetic field. (ii) Geodetic measurements on the size and shape of the earth can be made. (iii) Lunar mass can be measured from observation of satellites whose orbits pass near the moon. (iv) Ion densities can be determined when data from a satellite are coupled with certain precision radio techniques.

Total atmospheric thermal and visible radiation measurements. A satellite is in an ideal position to measure the total flux of radiation in and out of the top of the atmosphere. The incoming radiation, being primarily from the sun, is largely in the visible part of the spectrum, while the outgoing radiation from the atmosphere is infrared radiation plus the solar radiation which is scattered and reflected upward. These various fluxes can be sampled by a set of omnidirectional bolometers with coatings which are designed to absorb selectively a certain part of the spectrum. For example, a bolometer which is white in the visible but black in the infrared beyond about 4 or 5 microns will respond to the thermal radiation from the earth and atmosphere, while one with the reverse spectral characteristics will measure the direct and reflected sunlight. Further, a directional detector of visible radiation pointed toward the sun would, of course, monitor the incoming solar radiation alone. (Such a scheme is included in one of the IGY earth satellites.)

The purpose of this set of measurements is to determine the radiational heat budget of the earth and atmosphere. It is known that an excess of radiational energy is added to the atmosphere in low latitudes and that there is generally a net loss of energy from the polar regions. An understanding of this energy imbalance is basic to an understanding of the general circulation of the atmosphere. Furthermore, such a set of radiation measurements, provided that there were a reasonably fast response, would give a rough indication of the thermal inhomogeneity of the atmosphere and earth. It is likely that a measure of this inhomogeneity would provide an indication of the strength of the cyclonic and anticyclonic circulation. During periods of strong meridional transport of energy by the atmosphere there are rapid migrations, north and south, of warm and cold air masses, and these could probably be distinguished by their thermal characteristics.

Mapping of the cloud cover. On the sunlit side of the earth the contrast, in the visible and near-infrared, between clouds and ground or open water is considerable, and it has been demonstrated dramatically by the use of rocket and balloon photography that the existing weather can be traced by the large-area cloud patterns. These cloud patterns can be determined from a satellite by various means. A first approach, in which the scanning of the surface by photocells is performed by the uncontrolled rotation of the satellite, is being developed for the IGY program. In this case the reconstruction of the picture is complicated, however, and the data-handling capacity of the telemetering link places an upper limit on the amount of coverage and the degree of resolution.

The purpose of such an observation would be to show the cloud patterns over a large area of the earth with a degree of completeness not obtainable with present surface observation networks. For research in meteorology, this will throw new light on the way in which storm systems start and develop, on the broad

pattern of flow, on the effects of mountain barriers, and so on. If techniques are refined to the point where the observations can be made available to meteorologists immediately, this would represent one of the greatest advances ever made in the gathering of meteorological data and would surely improve short-term forecasting and the prediction of hurricanes.

Mapping of the night airglow and aurorae. The upper atmosphere in the 70- to 150-kilometer region continuously emits ultraviolet, visible, and infrared radiation. In middle and low latitudes this emission, called the "night airglow," is relatively steady but displays moving patterns. As is well known, the aurorae of the polar regions are tremendously variable. A world-wide survey, on the dark side of the earth, of this radiation, made in the general manner of the cloud-cover experiment but with greater sensitivity and less angular resolution, would provide a map of the activity of the emitting layers. The brightest lines of the upper air emission spectrum are the familiar 5577- and 6300-angstrom lines of atomic oxygen, the 5893-angstrom doublet of sodium, the OH bands in the ultraviolet and infrared, and the O_2 "atmospheric bands" in the infrared. The last mentioned may be the brightest of all when observed from outside the atmosphere.

The airglow and aurorae present moving, complex patterns which must be related to the meteorology of the 70- to 150-kilometer region. A map of the emission in various wavelengths, from the ultraviolet into the infrared, would therefore be an invaluable aid in the study of the behavior of this important part of the atmosphere. It is significant that changes in solar emission are undoubtedly first signaled by changes in the circulation patterns in this same region of the atmosphere and that these changes probably then work downward to affect the lower atmosphere.

Time fluctuations of solar ultraviolet and x-radiation. Solar ultraviolet and x-ray intensities are quite variable and appear to depend greatly on solar activity. Both x-rays and the ultraviolet are enhanced during a solar flare, in some wavelength regions by an order of magnitude or more. These fluctuations have corresponding effects in the earth's atmosphere. Increased output of hard x-rays, for example, causes a pronounced D-layer and an associated interference with radio communications. An increase in the intensity of near-ultraviolet solar light could contribute to the marked temperature excursions that have been noted in the ozone layer, and such temperature excursions undoubtedly interact with the surrounding wind patterns.

Since solar ultraviolet light and x-rays have such a pronounced effect on the atmosphere, and since their fluctuations are associated with important related effects, it should be very fruitful to monitor these solar wavelengths over a long period of time, say for a year, for the purpose of correlating the ultraviolet and x-ray intensity–time curve with weather, radio propagation, the ionosphere, airglow, winds, and so forth. Because these solar radiations are absorbed by the atmosphere, the logical place to monitor them is from above the appreciable atmosphere. This could be done from an artificial satellite orbiting entirely above 200 miles of altitude. By the use of suitable windows and gas fillings, photon counters and ionization chambers can be constructed to respond only to radiation within a restricted band. (Such a photon counter, sensitive to Lyman-alpha radiation, is to be flown on an early IGY satellite.) With such detectors, various bands from the near-ultraviolet down to the hard x-rays could be monitored. Payloads on the order of 50 pounds should be adequate to permit coverage of a number of important wavelength bands in a single installation having indefinite duration of operations.

Distribution of hydrogen in space. The density of hydrogen in interplanetary and interstellar space has been a subject of much interest and speculation. On the basis of astrophysical observations, the current estimate is about 1000 atoms per cubic centimeter in interplanetary space and about 1 atom per cubic centimeter in interstellar space, but the basis for these estimates is uncertain.

The density of hydrogen in space could be determined by observing the hydrogen Lyman-alpha radiation received from space and comparing it with direct solar Lyman-alpha radiation. Hydrogen ions in space would emit a more or less steady background of Lyman-alpha radiation as they captured electrons. Hydrogen atoms would fluoresce under irradiation by solar Lyman-alpha radiation, and this fluorescence would fluctuate directly with the solar curve. By analyzing the total intensity of Lyman-alpha radiation into the steady and solar-dependent components, one could determine the relative densities of hydrogen ions and atoms. With suitable calibration, the absolute densities could be determined.

The ionization chambers to be used to study solar Lyman-alpha radiation from an IGY satellite could also be used as the detectors for the hydrogen density experiment.

A valuable refinement of this type of observation would be the measurement of the contour of the Lyman-alpha line with high resolution. For this purpose, possibly, a very high order of reflection from a ruled grating combined with photoelectric scanning would be used. With such a technique it would be possible to obtain a resolution of a few hundredths of an angstrom, which is adequate to reveal the existence of an absorption core in the center of the line. Continuous measurements of this type from the satellite would reveal any temporal variation in the depth of the core of the line, and such measurements could give information about variations in the total neutral hydrogen content in the space between the satellite and the sun, and about the temperature of interplanetary hydrogen.

Survey of celestial sources in the far ultraviolet. Exploratory measurements made with rockets reveal a picture of stellar magnitudes in the far ultraviolet very different from that in the visible. Not only do the stellar emissions show anomalies in the ultraviolet but intense emission from ionized gas clouds has also been observed.

A satellite equipped with ionization gauges or photon counters with high sensitivity and restricted view could scan the sky with better aspect control than is possible with rockets and would provide a rough map of the ultraviolet "hot spots." Subsequent satellites with better orientation control could then survey these sources in more detail.

Extragalactic light. Among the many radiations which strike the top of the earth's atmosphere, the light from sources beyond our own galaxy is one of the most interesting, insofar as it contributes to our understanding of the astrophysical nature of the universe. The intensity of this extragalactic radiation is already known to be quite weak in comparison with the light from our own galaxy, and its spectral character is known to be heavily shifted to the red. These facts alone are subject to an immediate cosmological interpretation—namely, the expanding nature of the universe.

The hypothesis of the expanding universe can be submitted to a more specific test by detailed measurements of the spectrum of extragalactic light and by determination of the distribution of its intensity with respect to galactic latitude.

It is impossible to make such observations with ground-based or balloon-borne apparatus because of the great overburden of other radiations originating in the earth's upper atmosphere. One might suppose that they could be made with vertically fired rockets which surmount the major emitting layers of the atmosphere, but the intensity is judged to be so weak that the several minutes of a rocket's flight provide an inadequate period of time for significant measurement. A satellite, with its flight of longer duration, appears to be necessary for the accumulation of significant data.

The proposed apparatus consists of several high-sensitivity, photoelectric telescopes equipped with a variety of spectral filters—all operating in the visible region of the spectrum. This experiment seems properly classified as an exploratory one. Results are not assured, but if they are obtained they will be of very far-reaching and profound significance.

Cosmic ray observations. The objectives of a cosmic ray experiment would be: (i) to make comprehensive observations on the total intensity of the cosmic radiation as a function of latitude, longitude, altitude, and time; (ii) to determine whether the nuclei of lithium, beryllium, and boron are present in the primary cosmic ray beam and, if they are present, to measure their intensities; and (iii) to study, as in (i), the intensity of the heavy nuclei separately from the total intensity. Interpretation of the results of (i) and (iii) should yield a crucial test of the theory of the deflection of charged cosmic ray particles approaching the earth through the geomagnetic field and should yield new information on the nature and importance of interplanetary magnetic fields. The data of (ii) should settle one of the leading questions on the astrophysical origin of cosmic rays and on their propagation to the earth. The data from (i) and (iii) should provide a greatly improved understanding of the systematic and sporadic fluctuations of the primary radiation, the astrophysical causes of these fluctuations, and their consequences, as reflected in the rate at which secondary cosmic ray phenomena occur within the atmosphere. A special question is whether the solar sources of cosmic rays yield the same distribution of nuclear species as the usual primary beam.

Primary auroral particles. The polar aurorae ("northern lights" and "southern lights") are caused by the interaction of energetic charged particles with the upper atmosphere. Due to their charges, these particles are deflected by the earth's magnetic field and are focused on the polar regions. It has been established that the intensity of these streams of auroral particles changes rapidly, apparently as a result of changes in the sun.

In order to observe these particles it would be necessary to have a satellite on a high-inclination orbit, since the flux is concentrated toward the poles. By means of simple satellite-borne detectors it will be possible to map out the impact zones of the primary auroral particles on the top of the earth's atmosphere and to observe their changes (local and worldwide) with time to a degree not ever likely to be approached by ground observatories. It will be possible to compare rapidly the northern and southern zones of incidence and to study efficiently the ways in which the position and configuration of these zones are influenced by and correlated with geomagnetic field disturbances.

The temporal variations of the incidence of auroral radiations can be comprehensively correlated with observable activity on the sun to an extent not presently conceived to be possible by any other method. In addition, the nature of the primary auroral radiations (that is, protons, electrons, heavy particles, and so on) can be comprehensively studied, as can their intensities and energy spectra. A comparison of these data with those from ground observatories should be very fruitful in establishing the physical processes which are induced in the earth's atmosphere.

These auroral observations are closely related to observations of the geomagnetic field. Indeed it would be desirable, in order to obtain mutually supporting sets of data, to have two satellites aloft simultaneously—one carrying a magnetometer and the other carrying auroral radiation detectors. Eventually it may be possible to have a single satellite carry both types of apparatus.

Micrometeorites. There are various estimates of the number of micrometeorites striking the earth's atmosphere, but few actual measurements. For the IGY it is planned to count such particles in one or two satellites. The limited instrumentation and limited time of operation of the equipment will, however, leave unanswered such questions as: What is the mass spectrum? What is the energy spectrum? What are the fluctuations in total intensity? How are these particles related to visible meteor showers? By use of a satellite capable of operating over a period of a year, equipped with calibrated microphones, thin diaphragms with photocells to observe punctures, electrostatic analyzers, and the like, most of these questions could be answered.

Magnetic field. The earth's magnetic field is mainly caused by the magnetization of the earth's mantle and the electric currents flowing in its liquid core; this main part of the field can be quite accurately measured by ground-level surveys or aerial reconnaissance. However, the variations in this main field that are of external origin, amounting to as much as 7 percent, say, are due to a variety of current systems in the ionosphere and above. (There are current systems induced in the earth also, but these are presumably secondary effects caused by phenomena at great altitudes.) A major source of geomagnetic variations are the direct current systems in the lower part of the E-region, which are below the satellite altitudes. However, at much greater distances, perhaps an earth radius or more, there may be another highly variable current system known as the "ring current."

With a satellite-borne magnetometer flying over a monitoring magnetometer on the ground, the two making simultaneous measurements of the magnetic field, it is possible to determine the horizontal flow of current between the ground and the satellite. The same technique can be used with two satellite magnetometers as they pass over each other. Thus, it is possible to map the electric current systems out through the region of the ring current.

The use of vertical rockets to do this same thing has already been mentioned. In some ways a rocket is superior to a satellite for magnetic measurements, since it can make a vertical profile from the ground up, and thereby determine where the electric currents lie. However, these currents are highly variable, and a satellite makes it possible to determine how they vary in time, how they are related to solar activity, and how they may vary in the horizontal. The ideal approach would be to use rockets and satellites in combination, thereby obtaining a more complete map of the geomagnetic field in three dimensions and in time.

Ionospheric observations. The ionized layers of the ionosphere (D, E, F_1, F_2) generally lie at altitudes of between 80 and 300 or 400 kilometers. They are therefore mostly below the altitude of the satellite. A number of effective methods have been suggested for measuring the total free electron density between the satellite and the ground, one being a measure of the difference be-

tween the angle of incidence of the radio tracking signal and the optical line-of-sight as the satellite passes over a tracking station. The difference is very small and barely measurable for the radio frequencies best suited for tracking and telemetering. In order to insure accurate tracking, the USNC–IGY satellites transmit primarily at 108 megacycles. However, a 40-megacycle transmission is also planned for some USNC–IGY satellites (one of the frequencies used in the Soviet satellites), and at this lower frequency more bending and dispersion of the radio waves will occur. The use of some of the techniques of radio astronomy would be appropriate for measuring this effect. The transmission of two or more frequencies simultaneously would give added meaning to the results. Another observation yielding total electron densities is the rotation of the plane of polarization of the radio wave, due to the Faraday effect. Such an observation requires the use of a high-gain antenna with a dipole, to sense the plane of polarization, and a knowledge of satellite orientation.

Another class of satellite radio experiments would make use of the satellite as a known source of radiation to measure certain aspects of the fine structure of the ionosphere. It is observed that radio stars fluctuate, and these fluctuations are in part due to ionospheric inhomogeneities of various sorts, some of which are in the E-region and some in the F-region. A satellite would permit these horizontal inhomogeneities (sometimes known as "ionospheric lenses") to be mapped, both in the horizontal and in the vertical. Since the satellite may at times be in or below the F-region, it will be possible to separate out the various effects of the two regions of inhomogeneity. An especially interesting aspect of the irregularities in ionization of the upper atmosphere is the pattern of the auroral clouds, streamers, draperies, and so on, which extend from the E-region upward to great heights. These patterns are marked by visual radiation, as is well known, but they are also regions of intense local ionization. The radio signal from a satellite in the auroral zone would be influenced by the auroral ionization, and presumably a study of the fluctuations would tell a great deal about the character and distribution of the ionization in this region.

It should be borne in mind that the gross structure of the ionized layers can be measured from the ground continuously with ionospheric recorders, and that the general features of the ionosphere are already quite well understood. Furthermore, as was pointed out above, the fine structure of the ionospheric layers can probably best be determined by a rocket which penetrates rapidly through the ionosphere, recording successive changes in "radio depth" as it goes. However, it is certain that valuable ionospheric experiments can be made by means of satellite radio transmissions, and the experiments described above will be possible with any satellite which provides a more or less steady signal with stable frequency and known polarization.

To date, no experiment has been proposed which can measure the free electron distribution above the top of the ionosphere from a single satellite without serious difficulties due to the dominant effects of inhomogeneities in the ionosphere itself and uncertainties in the orbit, which tend to mask any second-order effects at the satellite altitude. However, the distribution of free electrons above the ionosphere would be of great significance. The use of two satellites, with a two-frequency transmission link between them, offers an apparently feasible solution. Another possible technique would be the use of a miniature-sweep frequency ionospheric sounder in the satellite, directing its pulses downward.

Biological experiments. Biological experiments should be instituted at the earliest opportunity in the satellite program, since they will be crucial to the eventual attainment of manned space flight. There appear to be two main areas of concern: the biological effects of prolonged exposure to the radiation in space (cosmic rays and the various solar emissions), and the subtle and complicated effects of prolonged weightlessness.

With regard to the first, a program of exposure of biological samples and live animals to cosmic radiation at high altitude in balloons has been under way for some time, and at the altitudes attainable by balloons (over 100,000 feet) the cosmic radiation is essentially the same as at satellite altitudes. There are other kinds of radiation, such as solar ultraviolet and x-rays, which do not penetrate to balloon altitudes, but these can be reproduced conveniently in a laboratory. Thus, the use of a satellite for the study of radiation effects on biological specimens does not appear to be very rewarding.

For the study of prolonged weightlessness, on the other hand, there is no known substitute for a vehicle floating freely in space. Biological specimens and live animals have been successfully flown and recovered from high-altitude rockets, having been exposed for a few minutes to a situation of weightlessness. The second Soviet satellite carried a dog, thereby lengthening the duration of the period of weightlessness *ad mortuum.* The USNS–IGY satellite program includes a biological sample (yeast). These first attempts to study weightlessness will have to be greatly expanded in the future.

Advanced Satellite Experiments

Selective and directional thermal radiation measurements. Since certain constituents of the atmosphere, such as water vapor, ozone, and carbon dioxide, have strong absorption lines in the infrared region of the spectrum, a detector looking downward which is sensitive only in these regions does not "see" the earth's surface. Instead, it detects the radiation emitted upward from the upper levels of the constituent, the radiation from the layers below having been absorbed by the atmosphere. Thus, for example, a detector looking down at around 9.6 microns (in a strong ozone band) would receive the thermal emission from the top of the ozone region at about 10 to 30 kilometers of altitude; a detector looking down at around 6 microns (in a strong water-vapor band) would receive the emission from the top of the troposphere at 8 to 10 kilometers, above which there is relatively little water vapor. A quantitative measurement of the thermal radiation in one of these narrow spectral intervals gives a measure of the temperature (and, to a second order, density) of the emitting layer. A more detailed analysis of the variation of this emission with zenith angle can give the vertical distribution of temperature in the emitting layer. This experiment would require great detector sensitivity and a considerable degree of orientation control, particularly for the measure of the "limb darkening" just described. To be most meaningful, the record for an entire satellite circuit should be complete, probably requiring storage of data and retransmission over a telemetering station.

The purpose of such a set of measurements would be to map the effective temperature of various layers high in the atmosphere. Some of these layers are inaccessible to conventional sounding balloons, and even those which are accessible can only be sampled at a few

points. As meteorologists have obtained progressively more information about the synoptic conditions in the upper atmosphere (using balloons and occasional rockets, to date), they have gained more insight into the behavior of the atmosphere, and their ability to forecast the weather has gradually improved. However, balloons cannot penetrate the part of the atmosphere which is affected by solar ultraviolet radiation below about 0.3 micron (the ozone cutoff). It seems reasonably certain now that short-term changes in solar radiation have an immediate effect on parts of the upper atmosphere and that these effects propagate slowly downward in a complicated and as yet unexplained way. A synoptic satellite observation of the kind described would probably provide a direct measurement of the immediate effects of a solar disturbance on the thermal structure of the atmosphere. It would, therefore, be a key to the development of a physical basis for long-range weather prediction.

Selective and directional ultraviolet and x-ray measurements. As already pointed out, ultraviolet and x-radiation from the sun below about 3000 angstroms does not reach the surface, but is absorbed and scattered by various constituents of the upper atmosphere. In some wavelengths this radiation is absorbed in a relatively limited region. Thus, if one scanned the sunlit atmosphere from above, using a number of ultraviolet detectors, one would be able to obtain a vertical profile of several of the constituents. For example, by scanning with photon counters sensitive to 1400 to 1100 angstroms, it is possible to survey the vertical distribution of O_2 from the 100-kilometer level to the top of the ionosphere. At around 2500 angstroms one could determine the distribution of O_3 below 100 kilometers. Similar measurements in x-ray wavelengths would monitor density variations in the E and F_1 regions of the ionosphere.

These types of measurements have been proved in rocket experiments. With sufficient payload available, more refined spectroscopic surveys of the earth's atmosphere in the far ultraviolet should be possible; with the sun as a light source, its attenuation might be measured, or characteristic reasonance lines of the various constituents studied.

Astronomical spectrograms. A spectrograph mounted in an artificial satellite would be able to photograph the sun, planets, and stars completely free from interference by the atmosphere, thus extending the sensitivity far into the ultraviolet end of the spectrum and permitting a much more detailed study of these bodies than is now possible.

Spectrographs to do this job are, in essence, available. Suitable light collectors would have to be designed. A pointing control would be necessary. Such a control could probably be worked out along the lines of those now used in rockets, with a total weight of less than 30 pounds. To retrieve the film, it would be necessary to work out techniques for recovery of a capsule from the satellite orbit (or of the satellite itself); however, such techniques have already been proposed and are considered to be feasible within the expected weight limitations.

An alternative to the recovery of film is, of course, the electronic processing and telemetering of these observations. This is discussed further in the next section.

Ultraviolet photographs of the sun. Much of the photochemical and dynamical activity in the sun is associated with the emission of ultraviolet radiation. Photographs of the sun in various regions of the ultraviolet should permit localization of regions associated with the respective wavelength emissions and would be an important aid to understanding solar activity.

Suitable filters and ultraviolet-sensitized films are available for making such photographs. If necessary, pointing controls similar to those already used in rockets could be constructed for directing a camera at the sun. It would probably be desirable (but not necessarily essential) to recover the film after the pictures had been taken; however, as indicated above, it is believed that suitable techniques could be developed for the recovery operation.

In this type of experiment the use of photoelectronic recording and telemetering should certainly not be overlooked, however. Such a technique would be of great advantage, for example, if a more or less continuous picture was needed. A variety of approaches can be considered for obtaining photoelectronic pictures of the sun in the ultraviolet or x-ray region. For example, it is entirely possible to measure the distribution of Lyman-alpha radiation over the sun's disc by means of a photon counter with narrow field of view, sensitive to this line only. By using a simple scanning motion, it is even possible to obtain a crude picture equivalent to a television scan of about 20 lines' resolution in a rocket experiment, and the longer time available in satellite measurements would permit such scans to be made with more resolution and at other interesting wavelengths, such as the helium resonance lines at 584 and 304 angstroms, the MgX line at 625 angstroms, and various x-ray wavelengths.

Planetary spectrograms. A variation of the experiment on ultraviolet and x-ray measurements would be the measurement of the spectra of the various planets in the ultraviolet and infrared. All of the central planets have visible atmospheres, but the composition of these atmospheres is difficult to observe spectrographically from the ground, due to the presence of the same or similar gases (in differing proportions) in our own atmosphere. For example, the solar ultraviolet radiation reflected from these planets is completely absorbed by our atmospheric ozone, and large segments of the infrared radiation which is emitted are absorbed by water vapor, carbon dioxide, and ozone, plus other trace constituents such as methane and nitric oxide. A satellite would have a clear view of these planets.

The radiation from them is very weak, however, and would require quite accurate positioning of the spectrograph in order to provide long exposures with limited angular fields (in order to minimize the cosmic and stellar background). Moreover, it would probably be most desirable to recover the spectra in the form of exposed plates, though it is possible to telemeter the information to the ground.

An experimental test of the general theory of relativity. One of the predictions of the general theory of relativity is that the fundamental time scale of atomic phenomena (for example, frequency of emitted spectral lines) is influenced by the gravitational potential in which the emitting system is located. This prediction has received, thus far, only a very few observational verifications, and even these remain in a somewhat controversial state. It is conceivable that it may be possible to mount a so-called cesium or thalium "clock" in a satellite and a similar one at a ground station and intercompare the rates of these two clocks over an extended period of time. In accordance with the general theory of relativity, it is expected that there would be a systematic difference in the rate of running of these two "atomic clocks," because of the known difference of gravitational potential to which they are subjected.

The effect is a small one, and it ap-

pears that accumulated observation over a period of the order of a month may be required to surmount reasonable experimental errors in location of the position of the satellite and in ionospheric conditions. (Both effects, of course, influence the transit time of the transmitted intercomparison signal from the satellite to the ground station.)

A proposal is known to be currently under consideration for a similar intercomparison between clocks, one of which is located on a mountain and the other in a neighboring valley. However, if the technical problems can be adequately solved, it may be desirable to utilize a satellite for a more sensitive test of this very profound theoretical hypothesis under different conditions.

Solar (cosmic) radio noise in the high-frequency and low-frequency spectrum. High-frequency radio waves below about 5 megacycles cannot penetrate the ionosphere, and even radio waves at 20 megacycles are sometimes totally absorbed. Thus, it is not possible to observe from the ground the lower frequency end of the radio noise which comes from the sun and beyond.

A satellite would, of course, not suffer from ionospheric absorption, but the signal levels in this region are low, and the antennas required to obtain much gain have to be large. However, by the use of long wires, or large erectable reflectors or lenses to concentrate the signals and to obtain directionality, measurements could be made on high-frequency signals below the ionospheric cutoff.

Collection of micrometeoritic samples. If techniques can be worked out for recovery of the satellite or of small capsules from the satellite, a long-period collection of micrometeorite particles could be made. These samples could be collected in containers filled with something like silicone grease, which could be opened while the satellite is on orbit and then closed just before the recovery operation is begun.

The recovery of a representative sample of meteoric material would be of value for a number of reasons: It would throw light on the relative abundance of elements in the solar system; it would help to resolve the questions concerning the scattering effect of this dust, observed as the zodiacal light; it would supplement the previously mentioned satellite observations of the impact effects of meteors; and so forth.

Manned satellites. Later in this article manned space flight is discussed briefly, and it is pointed out that man will inevitably venture into outer space sooner or later. Whether the presence of a man in the vehicle will contribute to our knowledge of the universe is beside the point. Such an achievement should, perhaps, be considered as an end in itself—the ultimate biological experiment.

Lunar Investigations

One of the major justifications for building and launching a rocket to the moon is the knowledge which would be obtained about our nearest neighbor in space. The emphasis of the long-range program described here is on an orderly progression of technical development and scientific research into problems of outer space. In this context, the investigation of the moon is but a step to the investigation of the planets.

There are several potentially fruitful experiments and observations on the moon now being considered, some of which could be made by impacting the moon directly (the impact velocity would be about 9000 feet per second for a vehicle taking 2 to 3 days for the trip), some of which could be made by a satellite in a circumlunar orbit (this would be a special kind of satellite), and some of which would require the lowering of instruments to the surface. Ultimately there will be manned vehicles capable of landing on the moon.

The experiments which should take priority are, in general, those which give information about the moon as a whole, rather than about the particular point of impact—those that will reveal the most about the processes by which the moon was formed, its past history, and so forth, and that will be most useful in the planning of subsequent experiments. The three quantities to be measured which pertain to the moon as a whole are the lunar gravity or mass, the moon's magnetic field, and its atmosphere. Of these, probably the last is the only one which requires a landing on the moon. A further experiment, described more fully below, is the determination of the internal structure of the moon by seismic prospecting techniques; this will certainly require the landing of an instrumented package.

Measurement of lunar mass and gravity. Present estimates of the moon's mass, based primarily on observations of the motions of asteroids and of the motions of the earth's polar axis, have a possible error of about 0.3 percent. So great an uncertainty as this would affect any calculation of the trajectory of a moon rocket, since calculations must take into account the moon's mass. It is therefore desirable that one of the early moon experiments be devoted to a more precise measurement of this quantity.

There are two possible ways of going about this. The best way is to track the rocket as it approaches the moon and to deduce from the path which the rocket takes, and from the instant of its arrival, the force of the moon's pull at each point. This is entirely practical in principle, but it requires considerable accuracy in the tracking. The accuracy requirements almost certainly could not be met by an electronic tracking system on the earth. A radar altimeter and Doppler drift measurement from the lunar vehicle itself might provide sufficient accuracy for such a determination. The use of ballistic cameras which could position a large diffuse reflector or a flashing light on the vehicle against the star background is also a promising possibility for accurately determining the motion of a vehicle relative to the moon.

An alternative method would be to measure the lunar gravity from the surface of the moon directly, after the rocket had landed. This kind of measurement is relatively simple and can be performed by measuring the displacement of a known mass suspended from a carefully calibrated spring, by measuring the time-of-fall of a body in a known distance, by measuring the period of swing of a pendulum of known length, and so on. By any one of these techniques the gravity of the moon could be measured with an error considerably less than one part in a thousand.

A measurement of the lunar gravity at some point on the surface is not sufficient to determine the lunar mass, however. The other parameter is the square of the distance between the measuring point and the moon's center. The average radius of the moon is about 1740 kilometers. Some of the mountains of the moon have been determined to be more than 1.3 kilometers high. There are escarpments more than a kilometer high separating plateaus from low-lying plains or *maria,* and the crater bottoms are at a different level from the surrounding land. In fact, the variations between various parts of the moon's surface, since the so-called "continental" or "sea" areas are at different heights above the mean level, make a determination of the size and shape of the moon somewhat uncertain. According to Baldwin, the lunar bulge is 2200 meters (in the direction of

the earth), and the uncertainty in this quantity is about ±200 meters. This alone corresponds to a possible error in height above the moon's center of 1/10,000, and a corresponding error in the lunar mass determination of 0.02 percent. It would appear, therefore, that this may be the limiting factor in determining the lunar mass from an observation of lunar gravity on the moon's surface, but such an observation would still reduce the present uncertainty by an order of magnitude.

Direct measurement of the lunar magnetic field. At present there is apparently no evidence at all that the moon has a magnetic field. It must have one, however, since it could hardly have existed for so long in close proximity to the earth without experiencing some effect of the geomagnetic field. Furthermore, the lunar magnetic field would depend on the method of formation of the moon and on the magnetic field in which it existed during its formation.

If we consider that an approximate lower bound to the lunar magnetic field is the strength of the earth's magnetic field at a distance of 386,000 kilometers, then we would be faced with the problem of measuring a field of about 0.14 gammas. (The magnetic field at the surface of the earth is about 0.5 gauss, or 50,000 gammas.) Familiar techniques exist for measuring magnetic fields down to a few gammas, but this remnant of the earth's field may, by itself, be too small to be measured. Thus, the first measurement of the lunar magnetic field should be considered to be exploratory and should be made with as much sensitivity as possible.

It may be that the moon's field is much stronger than this, due, perhaps, to internal circulations while it was cooling; or it may be that the moon's magnetic field does not align itself with the extension of the earth's field. If either of these possibilities is found to be true, it would be a matter of considerable theoretical interest, since it might reveal something about the way in which the moon was formed and about the history of the earth-moon system.

If the lunar magnetic field is larger than the foregoing calculation indicates, another likely cause would be the retention of the larger magnetic field in which the moon was embedded at the time of solidification. It has been held that the moon was closer to the earth when it solidified, and so it may have been in a stronger field at this time.

Mass spectrographic measurements of the lunar atmosphere. It is customary to think of the moon as having no atmosphere at all. Astronomical observations have given no sure indication of a lunar atmosphere. Theoretical calculations on the persistence of any remnant of an atmosphere show that even the heavier gases, such as krypton, xenon, and perhaps CO_2, would slowly escape from the hot, sunlit side of the moon.

Nevertheless, there is a possibility that enough gas is trapped in the crust of the moon so that there is a steady leakage of this gas. The heavier gases would stay on the surface for awhile, so there would be a very tenuous but constantly replenished atmosphere. A measurement of the constituents of this atmosphere would reveal information about the rate at which these gases are being released by the crust. This would be of considerable help in understanding the constitution of the crust and the way in which the moon was formed.

It is possible to design a lightweight mass spectrograph which could give an indication of both the atmospheric density and the atomic mass distribution of the lunar atmosphere—or at least an estimate of an upper bound of the amount of each gas present. The University of Michigan has proposed a design for such a gas analyzer; it would work on the principle of an "omegatron," could possibly be used in a satellite vehicle, and would operate down to pressures of the order of 10^{-10} millimeters of mercury. If it could function in a satellite, then it should be able to function on the moon. There does not seem to be any sure way at this time of estimating whether the trace of a lunar atmosphere could be detected by an instrument operating at this level of pressure, but the experiment certainly warrants a try (perhaps preceded by the observation of pressure described in the following paragraph).

Pressure and density of the lunar atmosphere. A measurement of the pressure or density of the lunar atmosphere alone would not be as useful as a measure of the individual constituents, as suggested in the previous section. The only advantage would lie in the fact that a pressure measurement is simpler to make, in principle, than a mass spectrographic measurement. If weight or complexity were a problem, then it might be desirable to make a pressure measurement first. Once the existence or nonexistence of a measurable atmosphere had been established, the decision to operate a mass spectrograph could be made on a firmer basis.

Seismic and microseismic observations of the lunar crust. There are probably two *natural* sources of motion in the moon's crust: that caused by shifting, sliding, or folding of the crust and that caused by the impact of meteoroids.

In order for the first to occur, the center of the moon would have to be plastic or molten, like the center of the earth, since there could hardly be much shifting of the moon's crust if the moon were a rigid sphere. Occasionally there might be a landslide, due to small-scale fracturing of a cliff subjected to the large monthly temperature variations, but a landslide would probably not register as a "moonquake." It is an open question whether the moon has a molten interior. In the geologic past there seems to have been volcanic activity, and the *maria* appear to have been laid down as a covering of molten material. However, since man has been observing the moon, there has been no clear case of an active volcano on the moon, and so it may be completely solidified by now. Listening for moonquakes would be one way to find the answer to this riddle.

There is, however, no doubt about the fact that meteoroids are continually impacting the moon. Most of the particles from interplanetary space are very small, with diameters of less than a millimeter. These would have almost no effect on the moon's surface during our period of observation and would not cause any measurable microseisms. However, there is a definite possibility that several large particles might hit somewhere on the moon during the period of observation. Depending on their energies and their distances from the instrument, the impacts would be detected as waves in the crust, just as the impulse from explosions on the earth's surface is picked up hundreds of miles away. In the case of the moon there does not seem to be any way of determining how far away from the recorder a meteoroid hit, but it might be possible to get some useful information from the character of the pulse.

If an explosion (or explosions) could be created at a known time and at a place some distance from the recorder, then one could make full use of the powerful techniques which have been developed for seismic prospecting. For studies of the lunar subsurface and core, this would certainly be preferable to depending on meteor impacts. In order to use seismic prospecting techniques, one must know the distance between the explosion and the recorder, and the recorder must be able to measure the time-of-travel, and the character, of the shock wave. Actually, after traveling a short

distance in the lunar crust, the original shock wave would be broken up into a number of waves with different group velocities and modes of propagation, and the analysis would depend to a large extent on being able to sort out the various components of the wave. This would mean that the wave would have to be recorded with considerable time resolution, and the record would then be transmitted to the earth by a playback mechanism. This would allow one to expand the time scale of the record in order to accommodate the bandwidth of the telemetering link.

The source of the shock used in the seismic experiment, which must be at some known distance from the detecting instrument, could be a hydrogen or an atomic explosion, or possibly the impacting of another part of the vehicle system. For example, if a last stage similar to the Vanguard second stage, weighing about 800 pounds, empty, were used to start the instrumental section on its way, it would release an amount of energy on impact with the moon (at 9000 feet per second) equivalent to nearly the same number of pounds of TNT. Naturally, the instrument package would have to precede it and land before the impact of the booster occurred, but this would require only a small extra push to the package early in the flight.

A more elaborate experiment can be conceived, in which grenades could be ejected from the moon rocket, travel a known distance, and then explode on hitting the ground. This would give a pulse of known energy at a known distance from the seismograph. If this experiment were considered crucial enough, it could probably be performed, but considerations such as the weight of the auxiliary projectiles, the accuracy with which they could be aimed, the effects of rough terrain, and other problems make such an undertaking seem rather difficult.

Observations at the point of impact. As mentioned earlier, the most valuable experiments, at least in the initial stages of lunar exploration, are those which deal with the moon as whole. However, it is clear that there are a number of things concerning the surface on which the package landed which would be of great interest. Among the important properties which would lend themselves to measurements are: (i) temperatures of the surface and subsurface; (ii) surface hardness; (iii) chemical composition of the surface material.

The Soviets have suggested the use of mobile instrument carriers equipped with television links to the earth (called "tankette laboratories")—an interesting means of extending such local observations over a wider area.

Planetary and Interplanetary Investigations

The requirements for landing an instrument package gently onto the surface of the moon are roughly equivalent in difficulty to those for placing the same weight of instruments on a collision course with either Mars of Venus. The detailed problems to be solved are different, particularly with respect to guidance, but the propulsion requirements may actually be considerably less for the interplanetary flight. It should be noted that the velocity necessary to escape from the earth-moon system is less than 0.01 percent greater than the initial velocity required to just reach the moon.

To achieve a heliocentric orbit is in many respects easier than to achieve an interplanetary (that is, planet-to-planet) trajectory, since the propulsion requirements are about the same while the guidance accuracy required would probably be less, depending on what is expected of the orbit. For this reason, it is not unreasonable to treat interplanetary and heliocentric flights together, even though the scientific objectives may be quite different.

One of the major problems in unmanned interplanetary flight will be that of communications and tracking. For example, at the distance of Mars at closest approach (about 50,000,000 miles, on the average), it would require an astronomical telescope with a 20-inch aperture to see a sphere of 1 kilometer diameter with an albedo of 1 (a white surface). This suggests that very large inflatable balloons or corner reflectors will have to be used if the space vehicle is to be tracked optically, or it will have to carry a source of bright light. Tracking by radar is not out of the question, though powerful transponders would be required to allow the vehicle to be reached at such a range.

Communication over these great distances will obviously require a great deal of transmitted power. All other things being equal, the power required increases with the square of the range of the communications link. For example, it is claimed that an advanced narrow bandwidth (an effective predetection noise bandwidth of 10 cycles per second) telemetering system, called the Microlock system, can now be designed to reach 3000 miles with only one milliwatt of transmitted power. At the mean distance of Mars at closest approach, the power required for such a system would be about 200 kilowatts. There are undoubtedly other schemes which are better suited for this purpose, but the problem certainly requires attention.

Some of the scientific objectives of interplanetary flight—objectives which can only be attained by such an effort—are listed below. An attempt has been made to name the simpler experiments first, and it appears that these simpler ones would in every case yield information required for the planning of the succeeding flights.

Determination of the astronomical unit. The basic unit of length used in astronomy is the semimajor axis of the earth's orbit about the sun (the astronomical unit), now estimated to be 92,900,000 miles or 149,600,000 kilometers and known to only three or, at most, four significant figures. It is taken as the basic unit because the diameter of the earth's orbit is the longest baseline which terrestrial astronomers can ever achieve. The parsec, a derived unit of length which is commonly used to measure stellar distances, is the distance at which the astronomical unit subtends one second of arc. In order to relate the astronomical unit to our usual yardsticks, it is necessary to triangulate from the earth on interplanetary objects whose orbits can be observed and timed. The closest objects of this kind are the asteroids; but the closest asteroids are several million miles away, and so triangulation from a baseline on the earth on such an object cannot be carried out with great accuracy (as evinced by the uncertainties in the values given above for the astronomical unit).

The situation would be greatly improved if astronomers were provided with an "artificial asteroid," one which passed relatively close to the earth occasionally and which could be observed as it circles around the sun. Ways of making it observable will require further thought, as will the corrections which may have to be applied for solar radiation pressure, meteoric and coronal drag, the perturbations of the earth and planets, and so on. By the time this experiment is achieved there will probably be enough information available on interplanetary conditions to permit such corrections to be made quite precisely.

An improved value of the astronomical unit would reflect itself in improved precision in other fundamental constants.

For example, the constant of gravitation expressed in terms of the astronomical unit, the solar mass, and the mean solar day is known from astronomical observations to nine significant figures; the gravitational constant expressed in centimeter-gram-second units is known from laboratory measurements to only four significant figures. It is the low accuracy in the conversion factors between the two sets of units, especially the unit of length (astronomical unit to c.g.s.) which prevents astronomers from converting the more precise value of this fundamental constant to the c.g.s. system.

Determination of planetary masses. When the distances between objects in the solar system have been established more accurately, the next objective in astronautics would be the determination of the masses of these objects. It is necessary to know the mass of a planet in order to determine its effects on the path of a nearby space vehicle, so planetary masses will be an essential input in calculating interplanetary trajectories accurately.

It is just this relationship between planetary masses and trajectories which forms a useful basis for a mass determination. Space vehicles dispatched on paths close to the various planets would be accurately tracked (perhaps with auxiliary position sensors in the vehicles themselves, such as star trackers and radars). From a precise trajectory the planetary mass would be deduced.

Entry into planetary atmospheres. As noted above in connection with advanced satellite experiments, it will be possible to learn a good deal about the planets and their atmospheres from satellite observing stations. However, a logical prelude to an actual landing on a planet (though probably not a necessity in the case of Mars or Venus) would be the observation of the behavior of an instrumented "reentry body" as it plunged into the planet's atmosphere. From a knowledge of its approach trajectory and a time history of altitude, deceleration, and vehicle surface heating, the atmospheric data necessary for designing subsequent entry vehicles could probably be determined.

Of course, the planets differ tremendously. Present estimates indicate that it would be even easier for a satellite to penetrate the atmospheres of Mars or Venus, given a slanting approach, than to return to the earth. The atmosphere of Mercury is essentially nonexistent. It is for the larger outer planets that such atmospheric entry bodies, or probes, would be most useful. This is discussed further in the next section.

Landing on the planets. Clearly, each planet is unique in its characteristics, and so the objectives and techniques for a landing vehicle would be different for each planet. Mercury, small and sun-scorched, poses many of the same problems as our moon. Venus and Mars, the most intriguing planets as well as the closest, will undoubtedly merit attention first, and the problems associated with the placing of instruments on their surfaces are so similar to those involved in the placing of instruments on our earth's surface that development of landing schemes and experiments should be fairly straightforward, once the guidance and propulsion problems have been overcome. The large outer planets are altogether different from the inner planets, and there may be no such thing as "landing" on their inner cores, which very possibly are nowhere solid but may consist of a liquid center merging with a deep gaseous envelope. One might, instead, design a vehicle which would enter the atmosphere of such a planet and then settle to a certain density level, where it would float, like an inextensible balloon. As for Pluto, we can now only guess at what its atmosphere and surface are like.

To restrict the discussion to Venus and Mars, the significance of obtaining observations on the surfaces of these two planets is too obvious to require emphasis. Moreover, the number of things which one would wish to find out about these sister planets is overwhelming. The most compelling question is undoubtedly: What forms of life, if any, do these planets have?

For the purpose of paving the way for subsequent landings on these two planets by manned space ships, the following are probably the most important features to be determined: (i) atmospheric density and composition near the surface; (ii) the range of atmospheric temperatures and winds near the surface; (iii) gross terrain features, such as mountains, valleys, snow fields, and, at least in the case of Venus, possible rivers and seas. It must be remembered that the surface of Venus is unobservable in the visible or infrared, due to the continuous cloud deck, so one must both land to explore its surface and fly over it at relatively low altitude to map it by radar. Mars could probably be roughly mapped by aerial reconnaissance without penetration of its atmosphere, but it might be impossible to identify some features without a closer look; (iv) surface composition. One would expect the surfaces of these planets to be infinitely varied, as is the surface of the earth. Still, one would learn a great deal about the conditions to be encountered on landing if one had previous knowledge of the chemical composition of some representative soils, their hardness and depth, their moisture content, and so forth.

Manned Space Flight

Although it is impossible to predict how quickly man himself will follow his exploring instruments into outer space, the inevitable culmination of his efforts will be manned space flight and his landing on the nearer planets. It is clear that he can develop the ability to do these things, and it is hard to conceive of mankind stopping short when such a tempting goal is within reach.

The attainment of manned space flight, however, cannot now be very clearly justified on purely rational grounds. It is possible, at least in principle, to design equipment which will do all the sensing needed to explore space and the planets. Mobile vehicles could be designed to land and crawl across the face of each of these distant worlds, measuring, touching, looking, listening, and reporting back to earth all the impressions gained. They could be remotely controlled, and so could act like hands, eyes, and ears for the operator on earth. Moreover, such robots could be abandoned without a qualm when they ran out of fuel or broke down.

Though all this could be done *in principle,* there may be a point at which the complexity of the machine to do the job becomes intolerable, and at which a man is found to be more efficient, more reliable, and above all more resourceful when unexpected obstacles arise. It is, in a sense, an article of faith that man will indeed be required to do the job of cosmic exploration personally—and, furthermore, that he will *want* to do the job himself, whether required to or not.

With man's first venture into outer space, a new program of research and exploration will begin. The program described above will therefore be the prelude to the drama to follow.

News of Science

Space Program Offered by Killian Advisory Committee

On 26 March President Eisenhower made public a report on outer space prepared by his Science Advisory Committee under the chairmanship of James R. Killian, Jr. The study set forth a research program leading through automated exploration of the moon and planets to manned space flight. Following are excerpts from "Introduction to Outer Space."

". . . It is useful to distinguish among four factors which give importance, urgency, and inevitability to the advancement of space technology.

"The first of these factors is the compelling urge of man to explore and to discover, the thrust of curiosity that leads men to try to go where no one has gone before. Most of the surface of the earth has now been explored and men now turn to the exploration of outer space as their next objective.

"Second, there is the defense objective for the development of space technology. We wish to be sure that space is not used to endanger our security. If space is to be used for military purposes, we must be prepared to use space to defend ourselves.

"Third, there is the factor of national prestige. To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength.

"Fourth, space technology affords new opportunities for scientific observation and experiment which will add to our knowledge and understanding of the earth, the solar system, and the universe. . . .

"*The moon as a goal.* Moon exploration will involve three distinct levels of difficulty. The first would be a simple shot at the moon, ending either in a 'hard' landing or a circling of the moon. Next in difficulty would be a 'soft' landing. And most difficult of all would be a 'soft' landing followed by a safe return to earth.

"The payload for a simple moon shot might be a small instrument carrier similar to a satellite. For the more difficult 'soft' landing, the carrier would have to include, as part of its payload, a 'retro-rocket' (a decelerating rocket) to provide braking action, since the moon has no atmosphere that could serve as a cushion.

"To carry out the most difficult feat, a round trip to the moon, will require that the initial payload include not only 'retro-rockets' but rockets to take off again from the moon. Equipment will also be required aboard to get the payload through the atmosphere and safely back to earth. To land a man on the moon and get him home safely again will require a very big rocket engine indeed —one with a thrust in the neighborhood of one or two million pounds. While nuclear power may prove superior to chemical fuels in engines of multi-million-pound thrust, even the atom will provide no short cut to space exploration.

"Sending a small instrument carrier to Mars, although not requiring much more initial propulsion than a simple moon shot, would take a much longer travel time (eight months or more) and the problems of navigation and final guidance are formidable.

"*A message from Mars.* Fortunately, the exploration of the moon and nearby planets need not be held up for lack of rocket engines big enough to send men and instrument carriers out into space and home again. Much that scientists wish to learn from satellites and space voyages into the solar system can be gathered by instruments and transmitted back to earth. This transmission, it turns out, is relatively easy with today's rugged and tiny electronic equipment.

"For example, a transmitter with a power of just one or two watts can easily radio information from the moon to the earth. And messages from Mars, on the average some 50 million to 100 million miles away at the time the rocket would arrive, can be transmitted to earth with less power than that used by most commercial broadcasting stations. In some ways, indeed, it appears that it will be easier to send a clear radio message between Mars and earth than between New York and Tokyo.

"This all leads up to an important point about space exploration. The cost of transporting men and material through space will be extremely high, but the cost and difficulty of sending information through space will be comparatively low. . . .

"*The view from a satellite.* Here are some of the things that scientists say can be done with the new satellites and other space mechanisms. A satellite in orbit can do three things: (1) It can sample the strange new environment through which it moves; (2) it can look down and see the earth as it has never been seen before; and (3) it can look out into the universe and record information that can never reach the earth's surface because of the intervening atmosphere.

"The satellite's immediate environment at the edge of space is empty only by earthly standards. Actually, 'empty' space is rich in energy, radiation, and fast-moving particles of great variety. Here we will be exploring the active medium, a kind of electrified plasma, dominated by the sun, through which our earth moves. Scientists have indirect evidence that there are vast systems of magnetic fields and electric currents that are connected somehow with the outward flow of charged material from the sun. These fields and currents the satellites will be able to measure for the first time. Also for the first time, the satellites will give us a detailed three-dimensional picture of the earth's gravity and its magnetic field.

"Physicists are anxious to run one crucial and fairly simple gravity experiment as soon as possible. This experiment will test an important prediction made by Einstein's General Theory of Relativity, namely, that a clock will run faster as the gravitational field around it is reduced. If one of the fantastically accurate clocks, using atomic frequencies, were placed in a satellite and should run faster than its counterpart on earth, another of Einstein's great and daring predictions would be confirmed. (This is not the same as the prediction that any moving clock will appear to a stationary observer to lose time—a prediction that physicists already regard as well confirmed.)

"There are also some special questions about cosmic rays which can be settled only by detecting the rays before they shatter themselves against the earth's atmosphere. And, of course, animals carried in satellites will begin to answer the question: What is the effect of weightlessness on physiological and psychological functions? (Gravity is not felt inside a satellite because the earth's pull is precisely balanced by centrifugal force. This is just another way of saying that bodies inside a satellite behave exactly as they would inside a freely falling elevator.)

"The satellite that will turn its atten-

tion downward holds great promise for meteorology and the eventual improvement of weather forecasting. Present weather stations on land and sea can keep only 10 percent of the atmosphere under surveillance. Two or three weather satellites could make a cloud inventory of the whole globe every few hours. From this inventory meteorologists believe they could spot large storms (including hurricanes) in their early stages and chart their direction of movement with much more accuracy than at present. Other instruments in the satellites will measure for the first time how much solar energy is falling upon the earth's atmosphere and how much is reflected and radiated back into space by clouds, oceans, the continents, and by the great polar ice fields.

"It is not generally appreciated that the earth has to send back into space, over the long run, exactly as much heat energy as it receives from the sun. If this were not so the earth would either heat up or cool off. But there is an excess of income over outgo in the tropical regions, and an excess of outgo over income in the polar regions. This imbalance has to be continuously rectified by the activity of the earth's atmosphere which we call weather.

"By looking at the atmosphere from the outside, satellites will provide the first real accounting of the energy imbalances, and their consequent tensions, all around the globe. With the insight gained from such studies, meteorologists hope they may improve long-range forecasting of world weather trends.

"Finally, there are the satellites that will look not just around or down, but out into space. Carrying ordinary telescopes as well as special instruments for recording x-rays, ultraviolet, and other radiations, these satellites cannot fail to reveal new sights forever hidden from observers who are bound to the earth. What these sights will be, no one can tell. But scientists know that a large part of all stellar radiation lies in the ultraviolet region of the spectrum, and this is totally blocked by the earth's atmosphere. Also blocked are other very long wave lengths of 'light' of the kind usually referred to as radio waves. Some of these get through the so-called 'radio window' in the atmosphere and can be detected by radio telescopes, but scientists would like a look at the still longer waves that cannot penetrate to earth.

"Even those light signals that now reach the earth can be recorded with brilliant new clarity by satellite telescopes. All existing photographs of the moon and nearby planets are smeared by the same turbulence of the atmosphere that makes the stars twinkle. Up above the atmosphere the twinkling will stop and we should be able to see for the first time what Mars really looks like. And we shall want a really sharp view before launching the first rocket to Mars.

"A close-up of the moon. While these satellite observations are in progress, other rockets will be striking out for the moon with other kinds of instruments. Photographs of the back or hidden side of the moon may prove quite unexciting, or they may reveal some spectacular new feature now unguessed. Of greater scientific interest is the question whether or not the moon has a magnetic field. Since no one knows for sure why the earth has such a field, the presence or absence of one on the moon should throw some light on the mystery.

"But what scientists would most like to learn from a close-up study of the moon is something of its origin and history. Was it originally molten? Does it now have a fluid core, similar to earth's? And just what is the nature of the lunar surface? The answer to these and many other questions should shed light, directly or indirectly, on the surrounding solar system.

"While the moon is believed to be devoid of life, even the simplest and most primitive, this cannot be taken for granted. Some scientists have suggested that small particles with the properties of life—germs or spores—could exist in space and could have drifted on to the moon. If we are to test this intriguing hypothesis we must be careful not to contaminate the moon's surface, in the biological sense, beforehand. There are strong scientific reasons too, for avoiding radioactive contamination of the moon until its naturally acquired radioactivity can be measured.

"And on to Mars. The nearest planets to earth are Mars and Venus. We know quite enough about Mars to suspect that it may support some sort of life. To land instrument carriers on Mars and Venus will be easier, in one respect, than achieving a 'soft' landing on the moon. The reason is that both planets have atmospheres that can be used to cushion the final approach. These atmospheres might also be used to support balloons equipped to carry out both meteorological soundings and a general photo survey of surface features. The Venusian atmosphere, of course, consists of what appears to be a dense layer of clouds so that its surface has never been seen at all from earth.

"Remotely controlled scientific expeditions to the moon and nearby planets could absorb the energies of scientists for many decades. Since man is such an adventurous creature, there will undoubtedly come a time when he can no longer resist going out and seeing for himself. It would be foolish to try to predict today just when this moment will arrive. It might not arrive in this century, or it might come within one or two decades. So much will depend on how rapidly we want to expand and accelerate our program. According to one estimate it might require a total investment of about a couple of billion dollars, spent over a number of years to equip ourselves to land a man on the moon and to return him safely to earth.

"The satellite radio network. Meanwhile, back at earth, satellites will be entering into the everyday affairs of men. Not only will they be aiding the meteorologists, but they could surely—and rather quickly—be pressed into service for expanding worldwide communications, including intercontinental television.

"At present all trans-oceanic communication is by cable (which is costly to install) or by shortwave radio (which is easily disrupted by solar storms). Television cannot practically be beamed more than a few hundred miles because the wavelengths needed to carry it will not bend around the earth and will not bounce off the region of the atmosphere known as the ionosphere. To solve this knotty problem, satellites may be the thing, for they can serve as high-flying radio relay stations. Several suitably equipped and properly-spaced satellites would be able to receive TV signals from any point on the globe and to relay them directly—or perhaps via a second satellite—to any other point. Powered with solar batteries, these relay stations in space should be able to keep working for many years.

"Military applications of technology. The development of military rockets has provided the technological base for space exploration. It will probably continue to do so, because of the commanding military importance of the ballistic missile. The subject of ballistic missiles lies outside our present discussion. We ask instead, putting missiles aside, what other military applications of space technology can we see ahead?

"There are important, foreseeable military uses for space vehicles. These lie, broadly speaking, in the fields of communication and reconnaissance. To this we could add meteorology, for the possible advances in meteorological science which have already been described would have military implications. The use of satellites for radio relay links has also been described, and it does not take much imagination to foresee uses of such techniques in long range military operations.

"The reconnaissance capabilities of a satellite are due, of course, to its position high above the earth and the fact that its orbit carries it in a predictable way over much of the globe. Its disadvantage is its necessarily great distance, 200 miles or more, from the surface. A highly magni-

Table 1. Timetable of scientific and technical objectives.

	Early
1.	Physics
2.	Geophysics
3.	Meteorology
4.	Minimal moon contact
5.	Experimental communications
6.	Space physiology
	Later
1.	Astronomy
2.	Extensive communications
3.	Biology
4.	Scientific lunar investigation
5.	Minimal planetary contact
6.	Human flight in orbit
	Still later
1.	Automated lunar exploration
2.	Automated planetary exploration
3.	Human lunar exploration and return
	And much later still
	Human planetary exploration

fying camera or telescope is needed to picture the earth's surface in even moderate detail. To the human eye, from 200 miles away, a football stadium would be a barely distinguishable speck. A telescopic camera can do a good deal better depending on its size and complexity. It is certainly feasible to obtain reconnaissance information with a fairly elaborate instrument, information which could be relayed back to the earth by radio.

"Much has been written about space as a future theater of war, raising such suggestions as satellite bombers, military bases on the moon, and so on. For the most part, even the more sober proposals do not hold up well on close examination or appear to be achievable at an early date. Granted that they will become technologically possible, most of these schemes, nevertheless, appear to be clumsy and ineffective ways of doing a job. Take one example, the satellite as a bomb carrier. A satellite cannot simply drop a bomb. An object released from a satellite does not fall. So there is no special advantage in being over the target. Indeed, the only way to 'drop' a bomb directly down from a satellite is to carry out aboard the satellite a rocket launching of the magnitude required for an intercontinental missile. A better scheme is to give the weapon to be launched from the satellite a small push, after which it will spiral in gradually. But that means launching it from a moving platform halfway around the world, with every disadvantage compared to a missile base on the ground. In short, the earth would appear to be, after all, the best weapons carrier. . . ."

Scientific objectives. "The scientific opportunities are so numerous and so inviting that scientists from many countries will certainly want to participate. Perhaps the International Geophysical Year will suggest a model for the international exploration of space in the years and decades to come.

"The timetable [Table 1] . . . suggests the approximate order in which some of the scientific and technical objectives mentioned in this review may be obtained."

Science Advisory Committee members: James R. Killian, Jr., *chairman*; Robert F. Bacher, professor of physics, California Institute of Technology; William O. Baker, vice president (research) Bell Telephone Laboratories; Lloyd V. Berkner, president, Associated Universities, Inc.; Hans A. Bethe, professor of physics, Cornell University; Detlev W. Bronk, president, Rockefeller Institute for Medical Sciences, and president, National Academy of Sciences; James H. Doolittle, vice president, Shell Oil Co.; James B. Fisk, executive vice president, Bell Telephone Laboratories; Caryl P. Haskins, president, Carnegie Institution of Washington; James R. Killian, Jr., chairman, Special Assistant to the President for Science and Technology, the White House; George B. Kistiakowsky, professor of chemistry, Harvard University; Edwin H. Land, president, Polaroid Corporation; Edward M. Purcell, professor of physics, Harvard University; Isidor I. Rabi, professor of physics, Columbia University; H. P. Robertson, professor of physics, California Institute of Technology; Jerome B. Wiesner, director, Research Laboratory of Electronics, Massachusetts Institute of Technology; Herbert York, chief scientist, Advanced Research Projects Agency, Department of Defense; Jerrold R. Zacharias, professor of physics, Massachusetts Institute of Technology; Paul A. Weiss, Rockefeller Institute for Medical Science.

Detection of Nuclear Explosions

American scientists have yet to reach agreement on the scientific question of whether a fool-proof monitoring system for nuclear weapon testing is possible. This first disagreement is at least partially responsible for a second—the policy question of whether the United States should enter into a pact with the Soviet Union to suspend tests. Thus, Edward Teller holds that "disarmament is a lost cause," while Harrison Brown, professor of geochemistry at the California Institute of Technology, charges that Teller is "willfully distorting the realities of the situation."

The scientific arguments in the disagreement have not been fully revealed, but in the March 1958 issue of the *Bulletin of the Atomic Scientists*, Jay Orear, who is assistant professor of physics at Columbia University, discusses four possible methods for detecting nuclear explosions. Orear has been a participant since 1957 in the Columbia Inspection Project, which is a private, unclassified study sponsored by the Columbia University Institute of War and Peace Studies. Orear says that since he has no access to classified material, he is "in the fortunate position of being free to say anything." Following are some excerpts from his discussion.

"An adequate inspection system for a test ban would require the establishment of monitoring stations at various locations deep inside the Soviet Union. About 25 such stations uniformly distributed throughout the Soviet Union should be sufficient. There is hope that such an inspection system would be acceptable to Russia, since it was Soviet delegate Valerian Zorin who proposed in the June 14, 1957 meeting of the U.N. Disarmament Subcommittee that the test-ban agreement 'be implemented by scientific control posts to be set up in the U.S., U.S.S.R., U.K., and Pacific Ocean areas.'

"The main techniques for detection of nuclear weapons testing are detection of: acoustic waves, seismic waves, electromagnetic radiation, radioactivity."

Acoustic waves. "Much of the radiation released in a nuclear explosion gets degraded by atomic processes to kinetic energy of the air molecules. Except in the immediate region of blast effects, this disturbance travels with the speed of sound and can be detected by sensitive microbarometers. This technique accurately gives the location and time of the test, and also gives a measure of the size of the explosion (yield in kilotons of TNT). The general feeling is that except for deep underground explosions, very high altitude tests, and tests of subnominal yield, nuclear tests can be detected at very large distances by this technique. Thus low-yield tests of just a few kilotons TNT equivalent would probably require monitoring stations inside the Soviet Union. Low-yield tests could probably be detected at distances up to a few hundred miles. If we require that every point in the Soviet Union be within 300 miles of a monitoring station, about 22 stations would be needed within the borders of the Soviet Union. This is assuming there are additional stations in the free nations bordering the U.S.S.R. A similar density of stations would be needed in other possible testing areas. In general, the microbarographic technique of detection is the most sensitive and would usually be the most relied upon."

Seismic waves. "In air and surface bursts, considerable blast energy is transferred to the ground. Thus, all tests whether underground or not, give rise to seismic waves which can be detected up

to a certain distance by seismographs. For example, the U.S. Pacific tests of 1954 were detected by seismographs in the United States, Australia, Pakistan, Japan, Greece, Sweden, Germany, South Africa, etc. Seismic detection techniques also tell the location and time of the explosion, and can determine the size of an underground explosion.

"As with the acoustic wave, the seismic wave cannot be detected at large distances for sub-nominal tests. For example, the underground Nevada test of September 19, 1957 was not detected in the eastern United States. The U.S. Atomic Energy Commission reported the yield of this test as 1 to 3 kilotons TNT. However, such underground explosions can be detected at distances of 300 miles and the signals can be distinguished from natural earthquakes. [On 11 March 1958 the Atomic Energy Commission confirmed that a small underground atomic explosion in Nevada on 19 September 1957 had been detected on official instruments more than 2000 miles away in Alaska. In a previous announcement the commission had stated that the explosion had not been detected beyond 250 miles.] The initial signal (at distances up to a few hundred miles) of a man-made explosion is a sharp pulse, while the signal from a natural earthquake is of much longer duration. The initial seismic waves from a bomb test are longitudinal and come from a point source, while natural earthquakes initially are predominantly transverse and usually come from a more extended and deeper source.

"For detection of nominal yield bombs at large distances, the acoustic detection appears more sensitive than seismic detection. In the case of deep underground tests one must rely completely on seismic detection since nearly all of the bomb's energy is dissipated underground. A chemical explosion of 0.06 kiloton has been detected by seismograph 240 miles away. . . ."

Electromagnetic radiation. "The high frequency end of the electromagnetic spectrum (x-rays, ultraviolet) is quickly absorbed in the atmosphere and converted to lower frequency electromagnetic energy and molecular energy. Thus an appreciable part of the bomb energy travels in the regions of the electromagnetic spectrum where there is little absorption; namely, as visible light and radio noise.

"Detection of the visible light at distances up to within 300 miles is quite simple. One merely points a photocell at the sky. It doesn't matter whether it is day, night, clear, or cloudy. As long as the test is not deep underground, a very distinctively shaped light pulse will be observed. The same mechanism which gives twilight when the sun (or bomb) is below the horizon will give a glow in the sky due to the nuclear explosion. Because of the large number of photons involved, one can detect light pulses very much smaller in intensity than the steady background intensity. Earth satellites could also be equipped to monitor the electromagnetic radiation emitted by a nuclear explosion. It also appears feasible to detect the light flash of the bomb from the moon. . . .

"The main limitation to electromagnetic radiation detection is the weakness of secondary scatterings. This technique is probably useful up to about 500 miles."

Radioactivity. "According to estimates of United States officials, one should expect that some of the future tests will be '100 percent clean,' and that some current tests have been 96 percent clean. One should keep in mind that '100 percent clean' is a practical impossibility due to neutron-induced activity in the bomb shell and atmosphere. This activity should be equivalent to up to 1 percent fission content, so that if we already have bombs with only 4 percent fission content, there is not much room for improvement.

"Because of the neutron-induced activity, all except the deep underground tests will produce radioactivity which may be detected. For example, the Japanese have detected low-yield Nevada tests by collecting dust from air at sea level.

"Because of the rapid decay, one would expect to obtain maximum sensitivity by collecting dust downstream from the test at high altitudes. The closer to the test, the greater the sensitivity. Collection at high altitudes and within 1000 miles of the test area would require monitor aircraft flying within the Soviet Union, which would require more sacrifice of internal security than fixed ground monitoring stations. Since the fixed monitoring stations at distances of 300 miles give adequate detection, one need not rely on detection of radioactivity. . . ."

Eisenhower on Eniwetok Test

At his news conference on 26 March 1958, President Eisenhower said that the United States will invite foreign scientists, including Russians, to watch a large nuclear explosion at Eniwetok Atoll this summer. One purpose of the explosion will be to demonstrate progress by American scientists in reducing fallout. The President also hinted that in seeking an agreement with the Soviet Union to ban future nuclear tests he might not insist on concurrent suspension of nuclear weapon production. This would represent a change from the Administration's present policy of linking the two items together.

Invitation to watch test. Following are excerpts from the President's comments on the United States invitation to foreign observers:

"In line with what I said to the press on July 3, 1957, the United States will demonstrate the progress our scientists are achieving in reducing radioactive fallout from nuclear explosions.

"To this end, for the first time at any test, we are planning to invite the United Nations to select a group of qualified scientific observers to witness at the Pacific proving ground this summer a large nuclear explosion in which radioactive fallout will be drastically reduced.

"We shall also invite—as we have on occasions in the past—a representative group of United States and foreign news media representatives.

"The United States scientists have been making progress in reducing radioactive fallout from nuclear explosions in the hope and belief that basic advances in both the peaceful and military uses of nuclear energy will thus be achieved. The advantages to mankind of continued progress in this field are obvious.

"The United States has always publicly announced in advance its nuclear testing programs. We trust that the forthcoming tests will provide valuable information to the world."

[At this point the President was asked whether he could specifically say whether observers from Russia and other communist nations would attend the tests.]

"Of course I cannot tell whether they will accept, but we are hopeful that the United Nations will designate the Scientific Committee for Detection, I believe it is, of radioactivity, that's about its name, and on that committee are the U.S.S.R, Czechoslovakia, the United States, the United Kingdom, Canada, and a few others and as a matter of fact Mr. Hagerty can give you also the entire list of nations. [Confers with Mr. Hagerty]. Mr. Hagerty wants me to read the full—the United Nations Scientific Committee on the Effects of Atomic Radiation, that's the name of the committee."

Baghdad Pact Nuclear Training Center

The Baghdad Pact Nuclear Training Center was established in Baghdad, Iraq, in 1956 by the member countries of the Baghdad Pact. W. J. Whitehouse of the Atomic Energy Research Establishment, Harwell, England, was the first director of the center and went there in 1957 with four other members of the Harwell staff. The center was formally opened by

King Feisal II on 31 March 1957, when Sir John Cockcroft was elected first chairman of its Scientific Council. H. A. C. McKay of the Chemistry Division at Harwell will succeed Whitehouse in July.

In its early stages the center is concentrating on the practical applications of radioisotopes to the problems of Middle Eastern countries and is organizing intensive short courses in the uses of these materials. Two instructors each from Iraq, Iran, Pakistan, and Turkey were trained at Harwell during 1956, and the United Kingdom also assisted by donating equipment and by providing staff to supervise, teach, and promote the development of the center until local personnel were sufficiently trained to take responsibility.

Grants, Fellowships, and Awards

Latin American Awards. On 1 July the Organization of American States will inaugurate a new fellowship program, recommended by the Inter-American Committee of Presidential Representatives, that will offer grants for advanced study or research to specialists throughout the Western Hemisphere. Qualified persons who are looking for an opportunity to do pure research, improve their professional skill through a postgraduate course, or enroll in an advanced technical course may apply now to the program. The program contemplates approximately 170 fellowships for 1958–59 and a minimum of 500 annually in the future. Grants will be made for periods ranging from 3 months to 2 years, covering such items as travel, registration and tuition fees, study or work materials, and room and board. Inquiries and requests for necessary forms may be obtained from: Technical Secretary, OAS Fellowship Program, Pan American Union, Washington 6, D.C.

Marine Biology. The Office of Naval Research and the Rockefeller Institute are jointly sponsoring the position of Jacques Loeb associate in marine biology at the Rockefeller Institute in New York and in its laboratories at the Marine Biological Laboratory, Woods Hole, Mass. Appointment will be for a period of 1 year, beginning on or about 1 September 1958. The purpose is to encourage the interest and increase the competence in marine biology of an outstanding teacher of biology, preferably in a liberal arts college, so that he may in turn, through his teaching, further the interests of his students in this field. An applicant should have a doctor's degree, at least several years of teaching experience, preferably be between 30 and 40 years of age, and be on leave of absence from his college or university. The stipend will be equivalent to his regular salary and employee benefits, with an additional allowance to cover extra costs incurred in moving, additional rent, and so forth. Applications for the position should be addressed to Detlev W. Bronk, President, Rockefeller Institute, New York 21, N.Y.

Scientists in the News

HERBERT F. YORK, director of the University of California Radiation Laboratory at Livermore, has been named chief scientist of the Defense Department's new space agency. In his new capacity, York will head the Division of Advanced Research Projects of the Institute for Defense Analysis. The institute, formed in 1956, is an association of five universities that provides the Secretary of Defense and the Joint Chiefs of Staff with scientific evaluations of potential weapons systems. EDWARD TELLER succeeds York as director of the Livermore Laboratory.

JOHN BUSHNELL, professor of horticulture at the Ohio Agricultural Experiment Station at Wooster, Ohio, for the past 35 years, has joined the research staff of the Growers Chemical Corporation, Milan, Ohio. He will study the relation of lime and fertilizer solutions to the specific gravity of chip potatoes.

LEON Z. SAUNDERS, former veterinary pathologist for the Brookhaven National Laboratory, has joined Smith, Kline & French Laboratories, Philadelphia, Pa., as supervisor of the newly created pathology and toxicology section. The section will centralize research on the effect, at the cellular level, of new agents in laboratory animals.

WAYNE O. SOUTHWICK, a member of the Johns Hopkins University medical faculty, has been appointed associate professor of orthopedic surgery at the Yale University School of Medicine, effective 1 July.

C. E. JACOB, ground-water consultant and former head of the department of geophysics, University of Utah, has moved his office from Utah to the Los Angeles area (Northridge, Calif.).

WALTER S. McNUTT, formerly assistant professor of biochemistry at Vanderbilt University and at present a senior research fellow at the California Institute of Technology, has been appointed to the staff of the Connecticut Agricultural Experiment Station, New Haven. He will conduct research in the department of soils and climatology on the biochemistry of environmental effects on plants.

Sir MACFARLANE BURNET, director of the Walter and Eliza Hall Institute for Medical Research at Melbourne Hospital, and professor of experimental medicine at the University of Melbourne, is delivering the 14th biennial Flexner Lectures at Vanderbilt University School of Medicine. The first three lectures of the series, which deals with "Clonal Selection as Exemplified in some Medically Significant Topics," were delivered in March. The final three have been scheduled for 7 April, 25 April, and 28 April.

ELLIS ENGLESBERG, bacteriologist with the Long Island Biological Association, Cold Spring Harbor, N.Y., has been appointed full professor in the department of biological sciences at the University of Pittsburgh.

HAROLD F. TANKE, technical staff officer of the Radio Technical Commission for Aeronautics Secretariat, Washington, D.C., for the past 8 years, resigned this position in March. He is returning to duty with the Civil Aeronautics Administration as an electronics engineer in region 4, Airport Station, Los Angeles, Calif.

JOSEPH V. CHARYK, formerly director of the aeronautics laboratory of Aeronutronic Systems, Inc., a subsidiary of Ford Motor Company, has been named director of missile technology. Operations will be carried out at Aeronutronic's headquarters in Glendale, Calif., and in experimental and test facilities under construction in Newport, Calif.

PAUL WEAVER, professor of geology at Texas A & M College, has received the Sidney Powers Memorial Medal of the American Association of Petroleum Geologists in recognition of his outstanding contributions to petroleum geology.

The tenth annual award of the Cornell University Medical College Alumni Association has been presented to PAUL F. RUSSELL of the Rockefeller Foundation "for his outstanding contribution to medicine."

A. STANLEY THOMPSON, nuclear scientist, who was formerly on the staff of General Atomic, a division of the General Dynamics Corporation, has joined the Nuclear Development Corporation of America, White Plains, N.Y., as manager of engineering operations.

***Erratum*: The third sentence of the legend for Fig. 2 of the report, "Blocking by picrotoxin of peripheral inhibition in crayfish," by W. G. Van der Kloot, J. Robbins, and I. M. Cooke [*Science* 127, 521 (7 Mar. 1958)] should have read "The inhibitory nerve was simultaneously stimulated at a rate of 21 stimulations per second (broken line) or at 150 stimulations per second (dotted line)."**

Book Reviews

The Voyage of the Lucky Dragon. Ralph E. Lapp. Harper, New York, 1958, xiii + 200 pp. Plates. $3.50.

Ralph Lapp has sympathetically and effectively chronicled the saga of the 23 unfortunate Japanese fishermen. Victims of the vagaries of an uncertain catch, they met the short-range fallout of the Bikini blast of 1 March 1954 and shared the unenviable distinction (with some Marshall Island inhabitants) of being the world's first victims of the H-bomb. Kuboyama, the single crew member who had any technical comprehension of the circumstances, ironically was the only one to die. For the others, the clinical phase has passed, but collectively they seem destined to play a political role for some time to come. Lapp's book, in this respect, is remarkably restrained, and he would have been remiss in his reporting had he not described at least the diplomatic and political repercussions among the Japanese and United States governments. In this respect the issue of contaminated tuna seems to have outweighed that of the injured fishermen.

In establishing the personalities of the principal fishermen, the book provides interesting detail on their way of life and on the skills necessary to sustain them. Later, the nuclear detective work of Japanese scientists, in the attempt to identify the nature of the fallout, is effectively woven into the fabric of the tale. It is clear, however, that the culprit (in their opinion and in Lapp's) was forejudged to be the U.S. Atomic Energy Commission. As the Japanese scientists ably demonstrated, the nature of the nuclear radiation to which the fishermen had been exposed was easily identifiable. Since the amounts and energies of the radiation were readily ascertained, it was possible to estimate the external exposure. It was not necessary, for immediate medical purposes, to know the isotopic origin of the radiation, so the demand for information on the composition of the bomb seems extraneous. But, regardless of the validity of the scientists' reasons for seeking that data, the narrative clearly shows that normal scientific curiosity is capable of penetrating many a classification barrier.

Pearl Buck provides a brief "Foreword" in which she says, "Innocent and industrious, pursuing their daily duties, these men are eternal symbols of what can happen to anyone, anywhere, unless —what?" It would be unfortunate if this query or indeed the events of Lapp's book were interpreted as applying to the problem of long-range or world-wide fallout. The latter is a separate, no less important, issue; unfortunately, no balanced discussion of it exists. But such is not the purpose of *The Voyage of the Lucky Dragon,* a highly readable and absorbing book, which is to be recommended to all, scientist and layman, who seek further understanding of our contemporary nuclear dilemma.

ARNOLD KRAMISH

Physics Division,
The Rand Corporation

Anatomies of Pain. K. D. Keele. Thomas, Springfield, Ill., 1957. x + 206 pp. Illus. $5.50.

From time immemorial both physician and philosopher have speculated upon the nature and meaning of pain. The physician's concern has been predominantly with pain as a symptom, local in origin, whereas the philosopher in the pursuit of sensibility in the pleasure-pain principle has treated it as a central phenomenon, material or immaterial. Eventually the two approaches meet in the physician and scientist. However, between these two positions the pendulum of opinion and experimentation has oscillated ever since, and no accord is yet in sight; if anything, the position is more uncertain than it was a few years ago, for we have come to recognize more clearly the difficulties of the problem.

The author, with very great skill, traces these fluctuating views from the earliest times to the present: from the concepts of primitive man of local spirit intrusion to Indo-European thought of the heart as the generalized center of sensitivity; to the debate of the Greeks, from Pythagoras to Galen, on the heart versus the brain as the organ of sensation; to the enthronement of the brain, and the search, from the mediaeval period to Descartes, Willis, Soemmerring, and Kant, for the *sensorium commune* and the residence of the soul; to the union of the local with the general by the discovery of the spinothalamic tract as a pathway for pain, with the contributions of Bell, Magendie, Schiff, Brown-Séquard, Voroschilov, Gowers, Edinger, and Spiller; to the laws of specific nerve energies and their local bases; and finally to 20th century ideas on the anatomy and physiology of pain mechanisms. This story of the great and continuing diversity well merits its title and fulfills well its object of tracing the anatomicophysiological concepts "which lie, often unconsciously, at the roots of our present ideas."

The work gains in strength and substance as it proceeds. The latter chapters are excellent, but the earlier, especially those which deal with the difficult Egyptian and complex Greek periods, leave something to be desired. For the Egyptian period the author has relied too much on a single and secondary source, Sigerist's recent *History of Medicine.* Following, but misinterpreting, his source, he states that there are two treatises on the heart and blood vessels, little realizing that the so-called treatise in the *Papyrus Edwin Smith* consists of three lines (I: 5 to 8) of a gloss which parallels a statement in *Papyrus Ebers.* But, more important, he is apparently quite unaware of the difference in meaning between *h3tj* (the heart as a physical organ) and *ib* (the heart and bowels as the center of consciousness and sensibility). So important was this distinction to the ancient Egyptian that it was preserved in the texts from the Pyramid age to the end of his civilization, in the Ptolemaic period. Further, it is quite incorrect to say that the ancient Egyptians had "no idea of a central nervous system" and that they allotted all sensory and motor functions to the heart and its vessels; even a very superficial acquaintance with *Papyrus Edwin Smith* would show this error. Likewise, the significance of the *mt · w,* or vascular system, is lost to the author; this is important, for this theory leads into early Greek conceptions and Aristotle's position.

There are a few minor annoyances, such as the consistent use of the noun for the adjective in the discussion of the ulnar nerve (pages 53, 58); praise for Galen's knowledge of the distribution of the ulnar nerve to "half of the middle finger" (page 51)—a distribution which would be highly exceptional; his citing of Tertullian (about A.D. 150–200) as, by some curious chronological inversion, supporting St. Jerome (about A.D. 340–420) (page 56); his crediting of Newton with a wave theory of sensation when his theory was corpuscular, as specifically mentioned in the very same paragraph of the *Principia* quoted (page 88); and

his ascribing of Spemann's "organisers" to Joseph Needham (page 64). In such an undertaking there are bound to be a few errors.

"To ignore the time dimension of any problem," says the author, "is to risk misunderstanding it. Particularly is this so if, as with regard to Pain, it involves neglect of the keenest and most brilliant thinkers the world has known." The history and thought on pain has been laid out before us, ably and well, in a book which all biologists and clinicians will find valuable as a means of increasing their understanding of this fascinating problem, perhaps justifying the author's hope that they will find there seeds worthy of germination.

J. B. deC. M. Saunders
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Vector Spaces and Matrices. Robert M. Thrall and Leonard Tornheim. Wiley, New York; Chapman & Hall, London, 1957. xii + 318 pp. $6.75.

Starting with the text by Birkhoff and MacLane in 1942, we have seen a steady succession of books designed to replace the traditional "theory of equations" course with one that presents portions of modern algebra at a level suitable for undergraduates. Some authors have centered on the notions of group and ring; others have elected to develop the basic concepts of finite dimensional linear spaces. All are motivated by the need to place this material at an earlier stage in the training of mathematicians, physicists, engineers, and behavioral scientists.

The present book belongs in the second category. In the first seven chapters (195 pages), the reader will find a detailed treatment of finite dimensional vector spaces over a field, and their associated linear transformations. Matrices appear as representations of transformations, under a specific choice of basis. The relations of equivalence and similarity for matrices are given brief treatments, with the latter confined for the moment to the case of distinct eigenvalues. Bilinear and quadratic forms are introduced, and the usual classification theorems for symmetric matrices are obtained. Determinants appear in chapter 3, defined by induction on the order; later, in chapter 6, they are characterized in the usual way as special multilinear functions. Chapter 4 contains a treatment of the solution theory for systems of linear equations.

The remaining four chapters (112 pages) take up some topics not usually regarded as suitable for an undergraduate course. There is an excellent treatment of the polynomial ring $F[x]$ over a field F and of the theory of simple algebraic extensions of F, presented as quotient rings of $F[x]$. This is used to discuss matrix algebras with entries in a ring and some of the simpler properties of vector spaces (modules) over a ring; for this discussion the ring of integers and $F[x]$ are chiefly used. Here also is to be found the general study of similarity for matrices with nondistinct eigenvalues, as well as many additional topics. Finally, the last chapter contains a terse account of some of the basic existence theorems for linear inequalities, with applications to linear programming and game theory.

The authors have produced a competent and comprehensive book; one who studies it with care, and masters the extensive collection of exercises, will emerge with an excellent command of the classical techniques of matrix theory and some appreciation of the more abstract approach. An instructor, however, might do well to examine several other books in this area before selecting this as the text for an undergraduate course. The pace is uneven; for example, in the space of several short paragraphs (page 61), one meets the concepts of group, ring, and algebra. Some key aspects of modern algebra, elementary in nature, are noticeable by their absence; in chapter 8, devoted to ring theory, the term *homomorphism* is used only in connection with a linear transformation (page 32), and no general connection is made later when ideals are introduced (page 205). Nevertheless, for a more advanced reader who already has some knowledge of the elements of algebra, the book will provide a detailed introduction to the classical matrix theory, out of which so much of the recent development in algebra has sprung.

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Phenazines. G. A. Swan and D. G. I. Felton. Interscience, New York, 1957. xix + 693 pp. $22.50.

This volume deals with the chemistry of phenazine (9,10-diazaanthracene) and its derivatives (by G. A. Swan of Kings College) and with the condensed mono- and polybenzophenazines and their derivatives (by D. G. I. Felton of the British-American Tobacco Company, Ltd.). These are treated essentially in the order in which they appear in Patterson and Capell's *Ring Index.*

Several dyestuffs of considerable commercial importance, such as the safranines, indulines, nigrosines, aniline black, and indanthrones, fall into this series, but the treatment is not one especially designed for a dye chemist but one adapted to the needs of any organic chemist interested in investigating these particular types. This is not a compilation of every such compound known, but it does make frequent use of tables to summarize many examples of a certain group. The text is documented with over 2000 references and has a section of addenda, including 145 references, which covers the literature through most of 1956.

This volume does an excellent job of reviewing this field thoroughly and expertly. The authors are to be congratulated on the service they have rendered. The formulas and tables are beautifully presented, and I have nothing but praise for the resulting product, which maintains the over-all high quality of the Weissberger series.

This is a very specialized book and a fairly high-priced one. Few will want it for their private use, but it should be a required addition to any technical library of organic chemistry.

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Department of Chemistry, Stanford University

Advances in Electronics and Electron Physics. vol. IX. L. Marton, Ed. Academic Press, New York, 1957. x + 347 pp. Illus. $9.

Volume IX of *Advances in Electronics and Electron Physics* represents a drastic, though temporary, change from the earlier volumes, being devoted entirely to geophysics. According to the editor: "In this volume, we have two aims: one is to help acquaint geophysicists and their allies with some of the modern methods at their disposal; and the other, to acquaint workers in electronics with the very interesting problems posed by geophysicists." After reading the volume, however, one is likely to conclude that the editorial aims and the contents are in only very partial agreement.

This is not meant to imply that the contents are not informative or interesting, for they are. But a geophysicist concerned with instrumentation, for example, will find it stressed in only two of the articles: "Electronics in oceanography" (J. B. Hersey) and "Contributions of electronics to seismology and geomagnetism" (B. S. Melton). On the other hand, a worker in electronics looking for interesting geophysical problems will find them primarily in the article "Aurora borealis" (C. T. Elvey) and in the article on oceanography already mentioned. Both of these, but especially the latter, will appeal to many readers.

The remaining articles are good re-

views that will appeal to the specialist rather than expositions for more general consumption. More or less in order of increasing specialization, they are: "Radio observation of meteors" (J. A. Davies), "Intensity variations in cosmic rays" (D. C. Rose), "Radio-wave propagation" (R. L. Smith and D. C. Rose), and "Negative ions" (L. M. Branscomb).

Now some concluding comments: A volume organized around a single theme can certainly play a most useful role. But, in my opinion, the results would be much more valuable for the regular subscribers to these volumes if the theme remained within the area normally covered. Cross-fertilization is an admirable goal, but it might be better for all concerned to leave this task to the several excellent publications that are exclusively devoted to it.

KEES BOL

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An Introduction to Automatic Digital Computers. R. K. Livesley. Cambridge University Press, New York, 1957. viii + 53 pp. Illus. + plates. $1.75.

This book provides a first, quick look at the digital computer, so that an engineer or scientist can make a rough appraisal of the value of using one in his work. The reader is expected to have no specialized knowledge of the field.

The emphasis is on the applications that can be made of an automatic digital computer and on what a person does in order to use it. The question of what is inside the machine is treated only to the extent necessary to provide enough background information to make the rest of the book intelligible to a scientifically inclined person.

In the first 13 pages the reader learns to program a simplified stored-program machine. This chapter can be merely read and it will seem plausible; but if the reader goes through the examples in detail and works the suggested exercises, he will learn what a stored program really is. It is well known that programming is learned best by doing rather than by reading. However, the more casual reader will find that he does not have to do the exercises in order to understand the rest of the book.

The next chapter treats input, output, and storage of numbers, so that one gets a rather good idea of how it is possible for a machine to do the things discussed elsewhere in the book. Then the subject of programming is considered in a qualitative, over-all way. Finally there is a discussion of what problems have been solved by machines, and of future prospects.

The principal shortcoming of the book is that the author does not seem to realize how good our modern machines really are, how bright the prospects for the future seem, and how deep an understanding of programming has been gained. This can probably be explained by the fact that he has been associated with the rather small machine at Manchester University rather than with the hundreds of much more powerful machines now in operation in the United States. The book is based on a set of lectures that were designed to acquaint people with this machine and with the general subject.

For example, he says, ". . . machine-produced programs take longer to run and use more storage space than the equivalent human product. . . . It does not seem likely . . . that machines will ever be able to carry out the broader aspects of programme design." However, modern automatic programming techniques often produce a better program than even very good human programmers, unless the human beings spend an uneconomical amount of time on the project. We have already done what Livesley predicts will never happen.

Then he says, ". . . the speed of a computer is 100 to 500 times that of a human being equipped with a desk calculator." There are hundreds of installed machines with a speed of 10,000 to 50,000 times that of a human being with a desk calculator. In the engineering stage are machines that are 100 to 1000 times again as fast.

With the exception of the overly conservative appraisal of achievements and prospects, the book is excellent, and it deserves to be read.

NATHANIEL ROCHESTER

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New Books

Naven. A survey of the problems suggested by a composite picture of the culture of a New Guinea tribe drawn from three points of view. Gregory Bateson. Stanford University Press, Stanford, Calif., ed. 2, 1958. 331 pp. $6.

Russia, the Atom and the West. George F. Kennan. Harper, New York, 1958. 125 pp. $2.50.

Psychotropic Drugs. S. Garattini and V. Ghetti, Eds. Elsevier, Amsterdam, 1957 (order from Van Nostrand, Princeton, N.J.). 620 pp. $19.50.

An Introduction to the Theory of Random Signals and Noise. Wilbur B. Davenport, Jr., and William L. Root. McGraw-Hill, New York, 1958. 402 pp. $10.

The Physical Chemistry of Electrolytic Solutions. Herbert S. Harned and Benton B. Owen. Reinhold, New York; Chapman & Hall, London, ed. 3, 1958. 836 pp. $20.

A Guide to Archaeological Field Methods. Robert F. Heizer. National Press, Palo Alto, Calif., ed. 3, 1958. 171 pp. $5.

Annual Review of Entomology. vol. 3. Edward A. Steinhaus and Ray F. Smith, Eds. Annual Reviews, Palo Alto, Calif., 1958. 526 pp. $7.

General Geology Laboratory Workbook. Physical geology and historical geology. Geology Department Teaching Staff, University of Texas. Samuel P. Ellison, Jr., Ed. Harper, New York, 1958. 295 pp. $3.75.

College Plane Geometry. Edwin M. Hemmerling. Wiley, New York; Chapman & Hall, London, 1958. 319 pp. $4.95.

Alcohol and the Jews. A cultural study of drinking and sobriety. Charles R. Snyder. Yale Center of Alcohol Studies, New Haven, and Free Press, Glencoe, Ill., 1958. 226 pp. $5.

A Primer for Coronary Patients. Robert J. Needles and Edith M. Stoney. Appleton-Century-Crofts, New York, 1958. 191 pp. $3.75.

Types of Graphic Representation of the Periodic System of Chemical Elements. Edward G. Mazurs. The Author, La Grange, Ill., 1957. 158 pp.

Aids to Public Health. Llywelyn Roberts. Baillière, Tindall & Cox, London, ed. 8, 1957 (order from Williams & Wilkins, Baltimore). 343 pp. $3.

The Threshold of Space. The Proceedings of the conference on chemical aeronomy. M. Zelikoff, Ed. Pergamon Press, New York and London, 1957. 353 pp. $15.

Mechanical Resolution of Linguistic Problems. Andrew D. Booth, L. Brandwood, J. P. Cleave. Academic Press, New York; Butterworths, London, 1958. 313 pp. $9.80.

The Development of Titrimetric Analysis till 1806. E. Rancke Madsen. Gads, Copenhagen, Denmark, 1958. 238 pp. Kr. 20.

Elements of Water Supply and Waste-Water Disposal. Gordon Maskew Fair and John Charles Geyer. Wiley, New York; Chapman & Hall, London, 1958. 622 pp. $8.95.

Observation and Interpretation. A symposium of philosophers and physicists. Proceedings of the ninth symposium of the Colston Research Society held in the University of Bristol, 1–4 Apr. 1957. S. Körner, Ed. Academic Press, New York; Butterworths, London, 1957. 232 pp. $8.

Toeplitz Forms and Their Applications. Ulf Grenander and Gabor Szegö. University of California Press, Berkeley, 1958. 252 pp. $6.

Chemistry Problems in Jet Propulsion. S. S. Penner. Pergamon, New York and London, 1957. 408 pp. $12.50.

Basic Feedback Control System Design. C. J. Savant, Jr. McGraw-Hill, New York, 1958. 434 pp. $9.50.

National Symposium on Vacuum Technology Transactions, 1956. 10–12 Oct. Hotel Sheraton, Chicago, Ill. Edmond S. Perry and John N. Durant, Eds. Pergamon Press, New York and London. 234 pp. $12.50.

Reaching Delinquents Through Reading. Melvin Roman. Thomas, Springfield, Ill., 1957. 140 pp. $4.50.

Principles of Economic Policy. Kenneth E. Boulding. Prentice-Hall, Englewood Cliffs, N.J., 1958. 448 pp. $7.95.

Reports

Temperatures of a Close Earth Satellite Due to Solar and Terrestrial Heating

For a satellite sufficiently high in the earth's atmosphere so that it has any considerable orbit lifetime, practically all heat exchange must be by radiation. Although considerable heat would be received from terrestrial reflection and reradiation, the predominant source will be solar.

The theory of planetary temperatures to be expected according to Stefan's law, $E=\sigma T^4$, has been treated thoroughly by several writers (*1–4*). A direct derivation, used by most writers, of the steady-state temperature of a surface at the earth's distance from a vertical sun utilizes the observed solar constant for E and the known Stefan-Boltzmann constant in the above equation. We will show here only an independent derivation of this temperature as found by utilizing the observed effective color temperature of the sun according to Wien's law as 6150°K, and the observed solar parallax, which implies a linear solar radius of 433,000 miles and a mean distance of 93 million miles. Thus, the radiation from the photosphere would lead to the relation for a black body giving maximum equilibrium temperature $T_{\max}$, at the earth's distance as:

$$\left(\frac{T_{\max.}}{6150^\circ\mathrm{K}}\right)^4=\left(\frac{433{,}000}{93{,}000{,}000}\right)^2,$$

giving

$$T_{\max.}=418^\circ\mathrm{K}.$$

This result is completely independent of pyrheliometric data; the latter yield a temperature some 25° lower. Observational confirmation of the present result is indicated by Pettit and Nicholson's determination (*4*, p. 118) of the central full-moon radiation temperature as 407°K, which, multiplied by the gray body approximation factor $(1+A)^{1/4}$, using their determination of the moon's radiometric albedo $A=0.093$, gives exactly 417°K as its true subsolar temperature. On a relatively rapidly rotating body such as an artificial satellite, no point except the pole of a spin axis directed toward the sun could satisfy even the geometric conditions, and its small size combined with good heat conductivity preclude any close approach to such a high temperature, even on the skin.

For points on a surface inclined by an angle ϕ to solar radiation, the energy received must be multiplied by cos ϕ. Since on a sphere the mean value of cos ϕ is ½, and only half the surface is sunlit at any moment, the mean incoming energy corresponds to ¼, and the resulting mean absolute temperature of all parts of the satellite to $(1/2)^{1/4}$ of the maximum found above—that is, $T_1=296^\circ$K for a black satellite in sunlight 100 percent of the time. Then, also, time spent in the earth's shadow is proportional to a further reduction in incoming energy, so that, in general,

$$T_1=(296^\circ\mathrm{K})\,(F)^{1/4},$$

where F is the fraction of time the satellite is sunlit, represents the time mean of temperature for all parts of the satellite due to direct solar heating alone. For a likely percentage of time in sunlight of 80 percent—that is, $F=0.8$—the corresponding mean $T_1=281^\circ\mathrm{K}=8^\circ\mathrm{C}$. Central internal parts of an artificial satellite would remain near 8°C; less protected parts near the surface might vary between 22°C or higher when the satellite is in sunlight, down to −6°C or lower when it is in eclipse. These are black-body temperatures and neglect all energy received from the earth.

The mean effect of terrestrial planetary *radiation* can be shown to be practically negligible, as follows. For a satellite at a height of 10 percent of the earth's radius, the radiation energy would fall off 20 percent, thus reducing the planetary temperature of 296°K by 5 percent to 281°K, which is identical with that due to solar heating, as found above for a satellite sunlit 80 percent of the time.

The effect due to terrestrial *reflection* of sunlight is much more considerable but uncertain, depending as it does on the mean radiometric albedo of the earth. Considering that Pettit and Nicholson (*4*, p. 134) have estimated the moon's radiometric albedo at less than 10 percent and that the lower latitude areas under the satellite may be darker than average, 30 percent seems a safe maximum estimate of the earth's effective radiometric albedo (*5*). Also, the maximum angular diameter of the earth from a satellite at workable orbital height is about 140°, so that it covers only $(1-\sin 20^\circ)=2/3$ of a hemisphere, and the mean cosine of reflection angle would be ½. Hence, the maximum estimated energy reflection from the earth to the satellite would be about 10 percent of that received directly from the sun. However, since the earth would be effectively "full" to the satellite only half the time on the average, the mean energy received should be increased by a factor of not more than 1.05 over that assumed for computing temperatures due to solar heating alone. These mean black-body temperatures should thus be increased by a factor of no more than $(1.05)^{1/4}=1.013$, leading to $T_2=(300^\circ\mathrm{K})\ (F)^{1/4}$, considering both solar and terrestrial heating. For a black satellite in sunlight 100 percent of the time, $T_2=27^\circ$C; for 80 percent in sunlight, $T_2=12^\circ$C. These are the highest mean temperatures to be expected, provided that the total solar absorptivity and thermal emissivity are equal (that is, the gray-body approximation holds) and that the satellite has no internal source of heat.

For an artificial satellite the total solar radiation absorptivity α and thermal emissivity ε of its surface can be determined experimentally before launching. The surface total reflectivity or radiometric albedo is $(1-\alpha)$. The resultant heating energy would be that of a black body, multiplied by α/ε, so that the actual mean temperature would be $T_3=(300^\circ\mathrm{K})\ (\alpha F/\varepsilon)^{1/4}$.

A recent report (*6*) gives these data for possible satellite shell materials. For typical aluminum alloys the ratio α/ε varies from less than 1/3 when the surface has been coated with silicone to about 3 when the surface is clean and polished. Since the resulting fourth root factors vary between 0.77 and 1.3, the corresponding range on mean temperature is

$$(231^\circ\mathrm{K})\,(F)^{1/4}<T_3<(390^\circ\mathrm{K})\,(F)^{1/4}.$$

Evidently the surface characteristics of an artificial satellite could be adjusted to produce any desired mean temperature within this range, say $37^\circ\mathrm{C}=310^\circ\mathrm{K}$ for $F=1$. For this temperature $\alpha/\varepsilon=(31/30)^4=1.13$ would thus be a satisfactory ratio of absorptivity to emissivity.

Finally, it should be emphasized that

All technical papers are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table *or* one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in *Science* 125, 16 (4 Jan. 1957).

the relations developed above specify how all these predicted temperatures depend upon the assumed effective temperature of the sun, and, to a much less degree, on the radiometric albedo of the earth. Reversing these relations, an immediate implication of the temperatures telemetered from actual satellites of which heating characteristics are known would thus be improved estimates of the heating characteristics of earth and sun.

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5. Visual albedo of 0.39 is given by A. Danjon, *Ann. Observatoire Strasbourg* **3**, pt. 3, 168 (1937).
6. G. B. Wilkes, "Total normal emissivities and solar absorptivities of materials," *WADC Technical Rept. 54-42* (1954).

5 March 1958

Difference in Response of Phosphatases in Chick Embryo to Injection of Substrate

Recent studies have shown that the administration of appropriate substrates, both in vivo and in culture, can bring about an increase in the activities of certain enzymes in tissues of the chick embryo (*1*). As part of our work on the functional differentiation of the small intestine (*2, 3*), we examined the influence of an injected phosphate ester on the alkaline phosphomonoesterase activity of the chick embryo duodenum. Obtaining positive results in this attempt, we have extended our investigations to other organs and to acid phosphomonoesterase in order to determine whether the response we obtained is peculiar to one phosphatase in one organ, or is more general. These experiments have led to the discovery that although alkaline phosphatase is always elevated under the conditions we have employed, acid phosphatase is in all cases unaffected or is decreased slightly.

In the tests reported here, 25 mg of disodium phenylphosphate in 0.1 ml of isotonic saline was injected into the chorioallantoic vesicle daily, beginning at 14 days of incubation. At 17 days the eggs were opened, the embryos were weighed, and samples of duodenum, liver, mesonephros, and metanephros were removed. Enzyme assays were run on total homogenates of these tissues, with phenylphosphate being used as substrate (*2*). Individual determinations involved from 0.5 to 1.5 mg of fresh tissue in 3.25 ml of fluid (approximately 2 to 10 μg of nitrogen per milliliter). The alkaline phosphatase was determined at *p*H 9.6 in the presence of 0.01M $MgCl_2$, the acid phosphatase at *p*H 5.4.

The results (Table 1) reveal that administration of substrate increases the alkaline phosphatase activity not only in the duodenum, in which the enzyme is normally accumulating rapidly during the test period, but also in the two kidneys, in which it is accumulating at a lower rate, and in the liver, in which it decreases somewhat. The effect on liver is also interesting because the enzyme is not associated with brush borders in this organ, as it is in the intestine and the kidneys. Acid phosphatase is not affected or is even lowered slightly in the same samples in which the alkaline phosphatase is increased. Total nitrogen content is not significantly altered by phosphate injection except in the metanephros, in which the nitrogen content of the experimentals is about 10 percent less than that of the controls.

Since duodenal phosphatase may be elevated in the chick embryo by adrenal stimulation (*4*), the possibility presents itself that the enzyme increases reported in this paper are secondary to a general stress effect resulting from the administration of an abnormal substrate, or from release of phenol from the substrate. This possibility may be eliminated, for three reasons. First, the treated embryos at 17 days are as heavy as the controls and are capable of developing normally beyond the test period; their mesonephric weights also are the same as those of the controls. Second, the administration of phenol and dibasic sodium phosphate in quantities equivalent to those contained in the disodium phenylphosphate used in the principal experiments brought about no change in the alkaline or acid phosphatase content of the duodenum. Third, phenylphosphate (but not phenol) produced a significant increase in the alkaline phosphatase content of isolated duodenal fragments cultured in Earle's saline solution or Eagle's nutrient medium, as compared with fragments cultured without substrate. Thus one may infer that the effects observed in vivo are not dependent on the intermediation of organs other than the affected organ. These experiments will be reported in detail later.

Other experiments now in progress are concerned with the effectiveness of other phosphate esters in inducing increase of alkaline phosphatase. Beta-glycerophosphate (25 mg/day) has thus far given only slight and inconsistent results. Phenolphthalein phosphate (25 mg/day) is ineffective. Beta-naphthyl phosphate (25 mg in 0.5 ml of fluid per day) produces no change after 2 days. Since both the acid and alkaline enzymes have strong affinity for all these substrates, it may be that in embryonic tissues, as in microorganisms (*5*), a suitable substrate is not necessarily an effective inducer. This point is being further examined in in vitro experiments.

The uniformity of the difference of response of acid and alkaline phosphatase in all organs studied suggests that the explanation for the difference is not to be sought in terms of the intracellular associations of the enzymes, which vary considerably among the tissues we have examined, but rather in the nature of the enzymes themselves, or in the enzyme-forming systems. Before this question can be profitably approached, it is necessary to consider whether the positive results we have obtained are due to

Table 1. Phosphatase in tissue of chick embryos injected with disodium phenylphosphate (+ Php) or saline (− Php) between 14 and 17 days of incubation. Phosphatase activity is given in micrograms of phenol liberated per 10 μg of nitrogen in 30 minutes. Each value is the average of 8 to 22 determinations and is followed by the standard error of the mean.

Tissue	Phosphatase activity				
	14 days − Php	17 days			
		− Php	+ Php	% difference	P
Duodenum					
alkaline	3.3 ± 0.17	8.7 ± 0.42	14.8 ± 0.85	+ 70.1	< 0.01
acid	1.9 ± 0.16	2.6 ± 0.15	2.8 ± 0.10	− 7.7	< 0.3
Liver					
alkaline	5.3 ± 0.36	4.7 ± 0.24	7.9 ± 0.43	+ 68.1	< 0.01
acid	4.9 ± 0.41	6.5 ± 0.32	6.3 ± 0.37	− 3.2	> 0.5
Mesonephros					
alkaline	18.4 ± 1.58	29.4 ± 3.13	48.4 ± 3.13	+ 94.1	< 0.01
acid	8.7 ± 0.32	11.5 ± 0.64	11.3 ± 0.33	− 1.7	> 0.5
Metanephros					
alkaline	9.8 ± 0.71	14.8 ± 1.12	42.5 ± 2.09	+ 187.1	< 0.01
acid	5.3 ± 0.29	7.6 ± 0.21	6.8 ± 0.23	− 10.5	< 0.02

the increase of a single alkaline phosphomonoesterase, or of a complex of phosphomonoesterases, or of one enzyme in a complex having many characteristics in common. This is among other aspects of the problem now being more fully investigated (*6*).

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Synergistic Action of Ethylenediaminetetraacetate and Radiation on Yeast

When radioisotopes are used as radiation sources in studies with growing cultures of microorganisms, it is essential that the isotope be kept evenly distributed throughout the suspension. This is particularly true with isotopes emitting alpha particles whose ranges are only a few microns. The use of plutonium and polonium as sources of alpha radiation in growing cultures is complicated by their tendency to be adsorbed on or taken up by the cells. The chelating agent ethylenediaminetetraacetate (EDTA) is known to depress the deposition and promote the excretion of plutonium in animals (*1, 2*). The present investigation was initiated to determine whether EDTA would also be effective in decreasing or preventing the uptake of plutonium in growing cells and permit the use of plutonium as an alpha radiation source in cultures of microorganisms.

Growth studies were conducted with a diploid strain of *Saccharomyces cerevisiae* cultured at 30°C in an autoturbidimeter which automatically recorded changes in the optical density of the suspension (*3*). Plutonium in 0.2*N* nitric acid was added directly to a sterile, chemically defined medium. Sodium EDTA was used at a concentration of 3×10^{-4} *M* in all tests except those designed to evaluate the effects of varying concentrations of this compound.

The growth of yeast in the presence of plutonium and EDTA is shown in Fig. 1(*A*). The increase in optical density of the cultures is indicated by a plot of autoturbidimeter readings against time. Growth was not altered by EDTA, but it was delayed approximately 3 hours by 0.5 μc of plutonium per milliliter. With EDTA and plutonium present, a synergistic effect was observed and the inhibition of growth was much more pronounced.

Because other work in our laboratories had shown that EDTA was metabolized by yeast, it appeared that this additional inhibition possibly resulted from EDTA carrying chelated plutonium into and concentrating it in the cells. To test this supposition the concentration of plutonium associated with the cells was tested in both growing and nongrowing cultures. Under both conditions less plutonium was associated with the cells when EDTA was present than when it was absent from the medium. From this it appeared that the effects from EDTA were not due to an increased radiation dose in cells exposed to EDTA and plutonium.

Since the EDTA appeared to augment the radiation effects from plutonium, it was necessary to determine whether this was specific for plutonium or was a general synergistic effect with any radiation. Beta radiation from tritium was used because the tritium would not be chelated by the EDTA and would be uniformly distributed through the culture. Tritium oxide was added to the sterile medium, and growth curves were determined as before. Figure 1(*B*) shows growth curves for yeast grown in the presence of tritium and EDTA. As before, EDTA had no effect on growth in the control tubes. Tritium, at 90 mc/ml of growth medium, produced a marked inhibition of growth. This inhibition was doubled by the presence of EDTA with this and lower concentrations of tritium. The effect of EDTA thus appeared to be that of a general synergistic action with radiation.

By employing higher concentrations of sodium EDTA it was possible to obtain greater synergistic effects of EDTA with radiation. However, higher concentrations of EDTA also inhibited growth in unirradiated control cultures.

These results suggested either that radiation increased the sensitivity of yeast to EDTA or that EDTA increased the sensitivity of yeast to radiation. If radiation increased the sensitivity of yeast to EDTA, then exposure of yeast to x-radiation with subsequent growth in EDTA should result in a decreased rate of growth. However, EDTA in the growth medium did not affect the inhibition of growth produced by a single exposure of the inoculum to 300,000 r delivered either at the rate of 2000 or 13,000 r/min. Also, incubation of yeast in EDTA for 2 hours prior to x-radiation did not

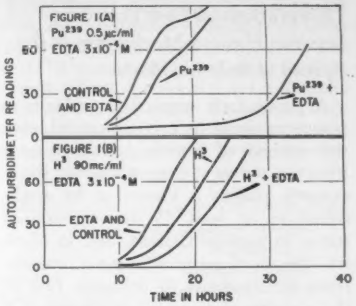

Fig. 1. Growth of yeast in the presence of (*A*) plutonium and EDTA and (*B*) tritium and EDTA.

alter its ability to grow either in liquid culture or on nutrient agar.

It is not possible at the moment to specify the mode of action by which EDTA amplifies radiation sensitivity. It appears probable, however, that the effect is produced by a general change in the electrolyte balance of the cell rather than by a specific deficiency of calcium since the addition of calcium to some of the cultures did not alter the effect of the EDTA. An effect of electrolyte concentration on the radiosensitivity of the respiratory system of yeast has been observed by Bair and Stannard (*4*). The ability of EDTA to produce chromosome aberrations and to increase the rate at which aberrations are produced by radiation administered at low dose rates has been reported by Wolff and Luippold (*5*), as have also more generalized effects on ionic balance which in turn affects chromosome behavior (*6, 7*).

Because EDTA increases the apparent radiosensitivity of yeast, its use in radiation studies may be limited to those in which this property is of interest (*8, 9*).

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Observations on Flea Transfer between Hosts; a Mechanism in the Spread of Bubonic Plague

A particularly important problem in plague epidemiology is concerned with the method of transfer of the disease from one rodent species to another. Since enzootic plague is known to be established in at least 15 of our western states, in western Canada, and in Mexico, the mechanism of plague transfer from wild rodents to domestic rats in the vicinity of human habitations is a particularly important question (*1*). Many investigators have suggested that the primary mechanism of plague spread is by transfer of infected fleas between hosts (*2*). Convincing circumstantial evidence that, in rural areas with a large rat population, the infection chain of "squirrel–squirrel flea–rat" may operate was obtained in studies of a plague epizootic in Ventura County, California (*3*). Although the evidence has been highly suggestive, the actual transfer of fleas from host to host has never been demonstrated.

The means for evaluating ectoparasite transfer more precisely were obtained through the development of a method for tagging fleas and other arthropods with Ce^{144} (*4*). By use of the California vole (*Microtus californicus*), domestic rats (*Rattus norvegicus*) and radioactively tagged wild rodent fleas (*Malaraeus telchinum*), a preliminary study of flea transfer was conducted in experimental plots simulating field conditions. These plots were enclosed by steel screens and provided soil and native grasses for the establishment of the rodents. In one type of experiment, male and female *Microtus* were toe-clipped for identification and allowed to establish nests; then tagged fleas were placed on certain individuals. Traps were set each day, and the captured animals were lightly anesthetized. The fleas were removed, and checked for radioactivity, and then returned to the hosts. In another experiment, three rats were maintained in a closure adjacent to three *Microtus* harboring tagged fleas, or the rats were allowed to enter the vole enclosure after the wild rodents had been killed or while they were alive. In all cases, a survey meter, Nuclear model 2612 equipped with a mica end-window probe, was used to scan the animals and fleas removed from them. The radioactivity of each flea was checked at the end of each trial with a RIDL scaler equipped with an end-window counter, Scott type.

Table 1 summarizes typical data on the movement of tagged fleas between individual *Microtus*. It should be noted that fleas transferred between animals, were found in nests, and were eaten by the animals, as was shown by radioactive feces. Thirty to sixty percent of the fleas were recovered from *Microtus* and their nests after periods ranging from 13 to 21 days.

The movement of radioactively tagged wild rodent fleas from the voles to the rats may be summarized as follows: 30 tagged fleas were introduced via the *Microtus*; while the *Microtus* were alive, none of these were found on the separated rats; after the *Microtus* were killed by snap-trapping, seven flea transfers were noted when the rats had entered the area with the dead voles; no transfers were noted on three new *Microtus* placed in the enclosure after the rats were again separated; 30 tagged fleas were placed on the new *Microtus*, and 12 transfers to rats were noted when the rats were allowed in the area with the live voles. Of the 60 fleas placed on the *Microtus*, none was found in *Microtus* nests, and 27 were recovered from the rats' nests. Radioactivity was found in *Microtus* feces twice, once in rat feces. Of the total fleas added, 49, or 81.6 percent, were accounted for during a period of 56 days. It should be noted that over 50 percent of the fleas accounted for were recovered between days 50 and 56. The fleas showed an initial average count of $(6.2 \text{ to } 8.5) \times 10^2$ counts per flea per minute, and after 56 days, $(3.6 \text{ to } 5.1) \times 10^2$ counts per flea per minute.

Under actual plague epizootic conditions, the coexistence of *Microtus*, *Malaraeus*, and *Rattus* has been postulated to be a significant relationship in a complex ecological situation in which other flea and rodent species are involved (*5*). Further studies on flea transfer under actual field conditions are being planned to confirm and extend the obserevations reported here (*6*).

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Table 1. Movement of radioactively tagged wild rodent fleas, *Malaraeus telchinum*, between one male and two female voles, *Microtus californicus*.

Trial No.	No. fleas added	Sex of host	Days of trial	No. flea transfers	No. times radioactive feces found	No. fleas recovered: Animal	No. fleas recovered: Nest	Percent fleas accounted for
1	40	M	18	21	4	11	16	67
2	10	F	21	9	not checked	5	no nest	50
3	10	F	18	21	not checked	3	no nest	30
4	12 ♂	F	6	8	1	0 ♂	0 ♂	36
	13 ♀	F				4 ♀	4 ♀	
5	15 ♂	F	13	40	not checked	2 ♂	3 ♂	62
	11 ♀	F				6 ♀	5 ♀	

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Presence of Polyamines in Certain Bacterial Viruses

Recent studies from this and other laboratories have shown the wide distribution of the polyamines putrescine $[NH_2(CH_2)_4NH_2]$, spermidine $[NH_2(CH_2)_3NH(CH_2)_4NH_2]$, and spermine $[NH_2(CH_2)_3NH(CH_2)_4NH(CH_2)_3NH_2]$ in nature (*1–3*). Little is known of their function, but their importance is implied by their roles as growth factors for several microorganisms (*4*) and as substrates for amine oxidases (*5*), and by their pharmacological effects (*1*). A possible functional connection with nucleic acids is suggested by the in vitro affinity of spermidine and spermine for nucleic acids and by the recovery of a considerable quantity of these bases from the nuclear fraction of liver cells (*3*). The studies on polyamines and the unanswered question about what compounds neutralize the negatively charged phosphate groups of the deoxyribonucleic acid (DNA) in bacteriophage (*6*) led to the present study of the polyamine content of phage.

Putrescine and spermidine are present in phage T_4 of *Escherichia coli* B in quantities sufficient to neutralize much

of the viral DNA; these polyamines appear to be the unidentified compounds recently found by Hershey to be injected into *E. coli* along with the DNA of phage T_2, while the phage protein remained outside (*7*).

Carbon-14 labeled putrescine is incorporated into spermidine in *E. coli* B, and these amines are then transferred to the phage. These findings are consistent with previous work showing that putrescine and spermidine are present in considerable amounts in *E. coli* (*2, 8*) and that spermidine is synthesized from putrescine and methionine (*9, 10*).

Cultures of *E. coli* B were grown in minimal medium (*11*), and were either harvested or infected with phage T_4r^+ while they were in the logarithmic phase. Putrescine and spermidine were extracted from suspensions of washed bacteria or purified phage (*12*) with hot 5 percent trichloroacetic acid. The bases were separated by ion-exchange chromatography on Dowex 50 (X2, 200–400 mesh) and were assayed colorimetrically as the dinitrophenyl derivatives, as previously described (*1*). Phosphate analyses were done on the phage after ashing (*13*).

The identity of the compounds recovered from the phage was established by ion-exchange and paper chromatography and by recrystallization with carrier to constant specific activity. Both compounds were eluted from Dowex 50 in the expected fractions, and the putrescine peak was further characterized by rechromatography on Amberlite XE-64 (*1*). Paper chromatography was performed in an isopropanol-HCl solvent (*7, 14*), which separates putrescine, spermidine, spermine, agmatine, and propanediamine. The putrescine and spermidine peaks from the Dowex eluates each showed single ninhydrin spots on the paper chromatograms. These spots had the same R_f values, respectively, as synthetic putrescine and spermidine (0.30 and 0.18) and contained all the applied radioactivity. Both compounds showed constant specific activity upon recrystallization with synthetic carrier (*3*).

Table 1 summarizes the results of several experiments. It can be seen that the putrescine and spermidine recovered from the phage are comparable in quantity to that recovered from either the uninfected or the infected bacteria. A comparison of the DNA phosphorus content with the polyamine content of the phage (noting two amino groups for putrescine, three for spermidine), shows that the neutralization of one-third to one-half of the DNA phosphate can be accounted for by polyamines. In four of the runs C^{14}-putrescine (*15*) was added with the bacterial inoculum, and from these it can be seen that the degree of dilution of the radioactivity is greater for the putrescine than for the spermidine; this is consistent with the higher rate of turnover of putrescine previously noted (*10*). The dilution of both polyamines is slightly greater in the phage than in the bacteria; this may be related to the length of time required after infection for complete lysis. In experiment 3 radioactive putrescine was added only after lysis of the bacteria; the absence of radioactivity from the phage recovered from this lysate rules out the direct exchange of the putrescine in the medium with that of the phage or the contamination of the phage with external putrescine. The variations among the several runs may be due in part to variations in growth conditions for the bacteria. It has been shown that the polyamines in *E. coli* vary markedly with growth conditions (*3*), and work is in progress to relate more precisely the host polyamines to those of the phage.

Table 1. Putrescine and spermidine content of *E. coli* B and phage T_4r^+. In experiments 1, 2, 3, and 4 the host bacteria were infected with about six phage each, and 5.5 hours later, when lysis was complete, the progeny phage were isolated; each run yielded about 4×10^{13} phage. The host bacteria were grown at 37°C with shaking in minimal medium (*11*) (1 lit except where noted) from a titer of about 10^8/ml to titers of 2.3, 1.5, 2.4, and 1.9×10^9/ml, respectively. Experiments 1A and 4A paralleled 1 and 4; the bacteria from the former two were harvested at the same time that phage were added to the latter two. Experiment 1B also paralleled 1, but here the bacteria were harvested 19 minutes after infection (before lysis had occurred). Analytical values for the purified phage were corrected for losses during purification.

Experiment	Putrescine (μmole)	Spermidine (μmole)	DNA phosphorus (μmole)	Ratio of specific activity of isolated material to that of added putrescine	
				Putrescine	Spermidine
1* (phage)	11.7	1.3		0.10	0.64
2* (phage)	4.9	1.3	46	0.22	0.65
3† (phage)	5.5	0.5	30	0.00	0.00
4 (phage)	6.1	1.2	43		
1A* (uninfected bacteria)	3.7	0.49		0.26	0.81
4A (uninfected bacteria)	4.1	0.61			
1B* (infected bacteria)	3.4	0.41		0.26	0.85

* C^{14} Putrescine (47,500 count/min μmole) added with bacterial inoculum: experiments of series 1, 4 μmole in 800 ml of medium; experiment 2, 11 μmole in 2 lit.
† 2.4 μmole of C^{14} putrescine was added to the liter of bacterial lysate after the first (low-speed) centrifugation and was incubated with the phage for 1 hour at 35°C and then overnight in the cold.

Hershey (*7*) has recently described two unidentified compounds A_1 and A_2 comprising about 1.5 percent of the total carbon in phage T_2; these compounds now appear to be spermidine and putrescine. Compounds A_1 and A_2 were labeled from C^{14}-arginine, which is a reasonable metabolic precursor of putrescine. Hershey reported that A_1 and A_2 were extractable from the phage with cold trichloroacetic acid, were unaffected by heating with 6*N* HCl, were ninhydrin-positive, appeared in the phage unchanged after assimilation by the bacteria, and seemed to be normal constituents of the bacteria. These properties are shared by the polyamines. In addition, spermidine was found to have the same R_f values as A_1 (the minor component) and putrescine as A_2 (the major component) in the solvents used by Hershey.

Paper chromatography of whole phage has also been performed in the isopropanol-HCl solvent. If 5×10^{10} purified T_4 phage (or T_2 phage) is applied to the paper, the strongly acid solvent extracts the amines from the phage, and two spots corresponding to putrescine and spermidine are revealed by developing with ninhydrin; the only other ninhydrin spot is at the origin and presumably is phage protein. It is interesting that the *Salmonella* phage PLT-22 and 98 (*16*) show quite different ninhydrin patterns from that of T_4. Chromatography of purified PLT-22 on paper and on Dowex 50 shows spermine but little if any putrescine or spermidine. However, these latter two types of phage were grown in broth, and the possible effect of different media on amine content remains to be assessed. At present the high amine content has been established only for certain types of coli phage, and further work is in progress on other viruses (*17*).

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17. We wish to thank Drs. H. Tabor and C. W. Tabor for their advice and helpful criticism.

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Gibberellin-Induced Systemic Fruit Set in a Male-Sterile Tomato

Table 1. Effect of gibberellin applied both to the foliage and soil on induction of fruit set in male-sterile Earlypak tomato.

Gibberellin per plant	Place of application	Average per plant: Total No. of clusters with fruits	Total No. of fruits	No. of fruits on treated lateral	No. of fruits on untreated lateral
100 μg	Expanded leaves	6.4	14.8	10.8	4.8
100 μg	Stem apices	7.0	12.0	7.0	5.0
100 μg	Flower peduncles	2.0	5.0	5.0	0.0
100 mg	Soil	8.0	36.0		
0	Control (untreated)	0.3	0.7		

Although recent reports (*1–3*) suggest that gibberellin or gibberellin-like substances (hereafter referred to as gibberellin) occur naturally in plants, investigators differ in their opinions regarding the movement of these compounds. The probability that gibberellin, like auxin, produces physiological effects distal from the site of synthesis indicates the need for further investigations of its movement in plants (*4, 5*). Hitchcock and Zimmerman (*6*) and Ferri (*7*) have demonstrated the movement of auxin through the plant by application to the soil, to roots, or to cuttings.

In the present study (*8*) the ability of gibberellin, applied as flower sprays, to set fruit parthenocarpically (*9, 10*) or to increase the growth of "dormant" tomato fruit (*11*) was regarded as a biological assay of its systemic movement.

The technique was refined by using male-sterile tomato plants (*Lycopersicon esculentum*) of the variety Earlypak (*12*) which were identified and selected at anthesis from a segregating backcross generation. These plants were normal in every respect except that the pollen grains were aborted (as indicated by an acetocarmine test). A few parthenocarpic fruit may set naturally on this mutant, but any appreciable increase in numbers of fruit under isolated greenhouse conditions could be attributed to applied gibberellin.

Immediately preceding anthesis of the first flower cluster, the main stems of the tomato plants were pruned in order to stimulate the growth of two lateral branches from the cotyledonary axils. These branches were nearly alike with regard to time of flowering, number of flowers per cluster, and number and length of internodes. Basipetal and acropetal movement from a treated lateral would be reflected in a stimulation of fruit set on an untreated lateral. The plants were grown during the spring and summer in a greenhouse held at approximately 65°F at night. Day temperatures were held between 65° and 85°F.

In preliminary experiments to confirm previous results (*13*), floral sprays containing 500 μg of gibberellin per milliliter resulted in characteristic parthenocarpic fruit development. Subsequently, the effect of gibberellin (*14*) on inducing systemic fruit set was evaluated (i) by applying, with a micropipette, 100 μg per plant to the first or second fully expanded leaf above the second open flower cluster, to stem apices, and to the peduncle of a single inflorescence (*15*) and (ii) by applying 100 ml of a solution containing 1000 μg/ml (100 mg) to the soil (Table 1). An excess of gibberellin was applied in order to compensate for the rapid degradation in the soil reported by Brian *et al.* (*16*). One milliliter of polyoxyethylene sorbitan monolaurate (Tween-20) per 100 ml of solution was added as a wetting agent for both plant and soil treatments.

Increased parthenocarpic fruit set on both treated and untreated laterals was induced by applying gibberellin to the foliage, but not by treating peduncles (Table 1). Greatest fruit set resulted from the soil application. Fruit from these treatments in every way resembled that resulting from direct floral sprays. All treatments, in addition to floral sprays, resulted in significant increases in size of "dormant" fruits. Johnson and Liverman (*11*) reported that a "dormancy" of developing fruits induced by high temperature or by far red irradiation could be overcome by spraying them with gibberellin. No quantitative studies were made to determine whether promotion of fruit growth in our experiments was comparable to that reported by Johnson and Liverman.

The marked increase in fruit set on an untreated lateral of a male-sterile plant indicates that gibberellin initiates a physiological response distant from the point of treatment. The results do not necessarily imply that gibberellin per se is directly responsible for systemic induction of fruit set. The use of male-sterile plants to assay for systemic fruit setting may have application for evaluating other growth-regulating substances.

ARNULF PERSSON
LAWRENCE RAPPAPORT
Department of Vegetable Crops, University of California, Davis

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16 December 1957

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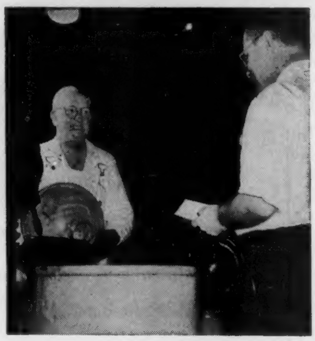

After this one, Mike Brethen's pay checks will have to follow him around in his retirement. He joined us right out of the Army in 1919 and wound up no less a craftsman than the old fellow who gets $65 for a pair of shoes. Rather than on a last or lathe, Mike's craftsmanship has been expressed over a big stoneware crock of acid with ice floating in it as sodium nitrite diazotizes an aromatic amine, after which he adds the resultant diazonium salt to the cuprous salt of whatever halide is required and gets an oily layer containing his aromatic halide. A Swiss chemistry lecture assistant named Sandmeyer proposed this eight years before Mr. Brethen's birth. Since many full-grown adult organic chemists despair of professional advancement from doing Professor Sandmeyer's reactions over and over again, a clear field was left Mr. Brethen to specialize in doing it very well.

On his last day at work he sat down and figured out he had run exactly 50 different versions of the Sandmeyer, counting the displacement of diazonium by iodine, which needs no copper.

Take *m-Dibromobenzene.* What could be simpler? Yet the other day we had a request for it from a man who is so eminent that organic chemists everywhere know his surname only as the designation for a certain green textbook 4½ inches thick. He couldn't find *m-Dibromobenzene* on the market, and he apparently thought it wise to let an expert make it, so the job fell to Mike Brethen. Now, therefore, it becomes Eastman 7276.

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Man comes home from work and his wife asks him what kind of a day he's had. "Same old yackety yak," he reports. "Heap-big all-afternoon powwow over the fact that whereas it used to take 0.019 roentgens of radium gamma radiation to produce a density of .05, they have now made x-ray film that takes 0.010 roentgens of gamma radiation to produce a density of .05. Cauliflower tonight again?"

•

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In case you have a friend who fails to grasp your explanation of the preceding paragraph and who has questions about this Type C – Type L – Type S *business, tell him to write to Eastman Kodak Company, Professional Goods Division, Rochester 4, N. Y.*

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Kodak

Letters

Population of Australia

In the issue of 3 January, Paul B. Sears [*Science* 127, 9 (1958)] cites the population density of the continents (page 11). His observations on "The inexorable problem of space" are so thoughtful and so timely that I venture to call attention to his estimate for Australia, which may confuse some readers.

The estimate given for Australia is 31 inhabitants per square mile. If this refers to Australia (and Tasmania) alone, the figure should be approximately 3.1 per square mile. It is probable, therefore, that Sears is referring to the entire southeast Asian archipelago, and that Indonesia, New Zealand, and possibly the Philippine Republic and Taiwan are to be included—the over-all average for these areas collectively would be in the neighborhood of 31 per square mile. But the figure given for Asia (78 per square mile) suggests that the offshore islands are included in the Asian estimate.

GEOFFREY BRUUN

Ithaca, New York

I am most grateful to Geoffrey Bruun and also to Chester Longwell for calling attention to this error.

The figures were obtained from a standard atlas. It is not available as I write, so that I am unable to say whether the datum given for Australia was intended for the whole of Australasia, a misprint, or my own error in copying, although I checked the table twice. I did, however, take the precaution to have my manuscript read by three very competent critics, none of whom caught the error.

The paragraph in question (page 11, column 3) should therefore be amended to read as follows:

"North America, including great areas of desert and tundra, follows with 23, while Africa and South America are nearly tied, with 17 and 19, respectively. The figure for the United States is 51, while Australia is the least densely populated of the continents, with about 3 persons per square mile."

I am obliged to M. B. Russell and Donald Jones for comments on the statement regarding corn production (page 13, column 2). Actually, both per acre and total production within the corn belt proper are greater than ever. It is the natural fertility—that is, that possible without fertilizer input—that has declined. The present high total yield can be even further increased, as I have said, but this fact must be weighed against increasing production costs and the present high rate of population increase.

Incidentally, Jones has reminded me

SEE PAGE 830

that geneticists who have written about future prospects are perhaps less sanguine than are soil specialists.

Cecil T. Blunn, of the University of Nebraska faculty in Turkey, at Ankara, has also called my attention to another detail (page 13, column 3, paragraph 1). He informs me that the individual Turk is anything but phlegmatic. Obviously I should have used the word *courageously* instead of *phlegmatically*. What I had in mind, of course, is the fact that neither the Finnish nor the Turkish Government has allowed itself to be stampeded. It is obvious from Blunn's letter that he admires the Turkish people very much, which is good news.

PAUL B. SEARS
Yale University,
New Haven, Connecticut

International Clearinghouse

Your editorial "Strength through union," in the 14 February issue of *Science* [**127**, 313 (1958)], discusses an issue of great importance to scientists. There is no doubt that we need a clearinghouse and coordination center for abstracting, indexing, retrieving, and translating the vast flood of scientific publications which is inundating us today and which will increase with time. There is much to be said for your conclusion that this service can best be performed by combining and coordinating private and governmental facilities and programs, and I was happy to learn that progress is being made in this direction.

It seems, however, that this is a problem of international scope; one that could and should be solved by an international clearinghouse. Such a world science literature center, organized, perhaps, under the United Nations, could abstract all the literature now being covered by Russian, American, and other abstracting agencies, and the abstracts, appropriately translated, could be made to meet the requirements of scientists throughout the world. To Americans and Russians this would represent a great saving in expense and technical manpower; to the scientists of many small countries it would mean the difference between participation and scientific isolation.

Scientists have often emphasized the international nature of their interests and activities. Unwittingly they may be drawn into the disruptive eddies of political currents and swept apart. Here, it seems, is an opportunity to forge a link across international lines which has great potential value to science and which could serve as a significant strand in the forging of broader bonds of understanding between nations.

JOHN T. EMLEN, JR.
Department of Zoology,
University of Wisconsin, Madison

Meetings

Ninth Pacific Science Congress

The small, forward-looking group of scientists, headed by the late Herbert E. Gregory, who organized the First Pacific Science Congress, held in Honolulu in 1920 (and known then as the Pan-Pacific Science Congress), could hardly have guessed the magnitude of the success that would in future years crown this pioneer effort.

It is an understatement to say that the Ninth Pacific Science Congress, held in Bangkok, 18 Nov. to 9 Dec. 1957, exceeded all expectations. The attendance of 860 registered delegates—the largest attendance at any Pacific Science Congress to date—included 500 foreign delegates and 360 delegates from Thailand. In all, 36 countries or territorial subdivisions (such as Hong Kong, Singapore, New Guinea, and the Ryukyus) were represented. Of the registered delegates, 228 were from the United States.

Notwithstanding the unexpectedly large attendance, all arrangements were adequate, everything proceeded

smoothly, scheduled events were held on time, transportation on excursions and field trips was more than sufficient. At the administrative headquarters and in the registration hall one found a combination of oriental calm, unfailing good humor, and a type of business efficiency that we complacently but wrongly characterize as "Western." The officers of the congress and the members of the various organizing committees deserve credit for an outstanding job of organization that reached down even to small details relating to the comfort and convenience of the visiting delegates.

Every morning buses called at all the major hotels to take delegates to Chulalongkorn University, where the scientific sessions were held. Then the buses came back for a second and sometimes even a third round to pick up those laggards who had missed the first. Luncheon was served on the campus every day—breakfast too, after the management discovered that too many people were missing the first bus. Meals served on the campus not only met important practical needs but afforded very pleasant social occasions, and further enabled one to find any particular person with whom he might wish to converse. Friend met friend from whatever continent, new acquaintances were made, committees met, and important business was transacted over the luncheon tables.

Scientific sessions were ordinarily held from 8:30 A.M. to 12:30 P.M., and the afternoon was thus left free for sightseeing or shopping. Because of the crowded program it was necessary to schedule some meetings from 2:00 to 4:30 P.M. But through good planning by the organizing committee, all delegates had some free time to enjoy Bangkok—a bustling, modern city of a million people that has managed to combine with its beautiful ancient temples and its picturesque canals such modern appurtenances as radio, television, streetcars, buses, tens of thousands of automobiles, and a king-size traffic problem that compares with that of San Francisco or New York. Two blocks from the hotel in which I stayed, workmen were busy at the remarkably occidental pursuit of widening a bridge to carry two more lanes of traffic.

The opening and closing plenary sessions were held in Santitham Hall, a fine, modern auditorium especially designed for international gatherings. The comfortable seats are arranged behind sweeping arcs of desks. At each seat there is a telephone dial with six numbers, enabling one to listen to an address in a foreign language and dial in to any one of six translations. This facility was not used at the science congress, all of the proceedings being conducted in English. Overseas delegates were impressed with the linguistic ability and ease of their Thai hosts.

At the opening session, Prime Minister Pote Sarasin, the honorary president, and Air Marshal Muni M. Vejyant-Rangsrisht, the president of the congress, addressed the delegates briefly and eloquently. The Prime Minister made three points: (i) the need for international cooperation in science; (ii) the need for complete freedom in scientific research; (iii) the essential humanitarianism of science, "which is its chief reason for being, its major justification." The president of the congress, who, in addition to being an air marshal, is also the rector of Chulalongkorn University, emphasized the responsibility of science "to exercise its rightful stewardship over the vast treasure of accumulated scientific knowledge." He said, further, "If the insanity of war again breaks loose . . . there will be no brilliant afterthoughts capable of calming the quarrels of the nations. There will be no civilization for science to serve."

The congress was held under the patronage of Their Majesties King Bhumibol Aduldej and Queen Sirikit of Thailand, who, in a precedent-shattering display of hospitality to a scientific gathering, entertained the entire group at a garden party at Amphorn Palace. After brief formal introductions of heads of delegations and section chairmen, for-

mality was dropped, and the royal couple mingled with and chatted with their guests for a good two hours, conversing with perfect ease in at least three languages.

The scientific program of the congress included more than 700 papers, divided among 18 sections. In addition to the submitted or invited papers, there was a symposium on "Climate, Vegetation, and Rational Land Utilization in the Humid Tropics," aided by UNESCO; there were the reports of the chairmen of standing committees of the Pacific Science Association; there were two sessions on "International Cooperation in Science"; and there were seven public evening lectures by distinguished speakers from three continents. Asia and Thailand were ably represented by Boonsong Lekagul, who gave a lecture on "Wildlife of Thailand," illustrated with excellent motion pictures.

Somewhat unexpectedly the U.S.S.R., which had not participated in the Seventh (New Zealand, 1949) or Eighth (Manila, 1953) Pacific Science Congresses, sent a delegation of nine to the Bangkok congress—eight scientists and an interpreter. The latter was a graduate student from the University of Moscow who had an excellent command of English. The scientists were well selected for this congress, being specialists on the marine biology and oceanography of the northwestern Pacific. All spoke either German, French, or English, so that communication presented no great problem. The pleasant and highly competent young interpreter was unobtrusive but available when needed. It was my impression that the Russians were welcomed as scientific colleagues, and that ideological differences were pushed into the background for the duration of the congress.

A feature of the Ninth Congress that left visiting delegates amazed and speechless with admiration and envy was the Documentation Section. I carried an extra suitcase full of mimeographed copies of documents pertaining to my section—a precaution that proved completely unnecessary. I could have got along perfectly well with one copy of each paper. The Documentation Section, set up at Chulalongkorn University, was equipped with two IBM electric typewriters, two multilith machines, and equipment for photographing line drawings, halftones, or handwritten script. It was also equipped with a highly trained crew that worked literally day and night and could reproduce anything in any language. They turned out documents in English, French, Thai, and Chinese, and everything came forth when needed. Twenty-four hours was the prescribed time for getting out 300 or 500 copies of a given document. But if a harassed chairman of a section came in at 9:00 A.M. with a set of resolutions

adopted by his section and said, "I need 300 copies of this by noon," he got 300 copies by noon. I watched this system to see whether it would break down under pressure, but it never did. It turned out over *three million pages* of multilithed material in two weeks. Never has a scientific gathering been better documented.

At the end of two weeks of deliberations the congress met for a final plenary session, at which Ian McTaggart Cowan, head of the Canadian delegation, gave a brief, brilliant address of thanks on behalf of all of the foreign visitors. This closing session was held on 30 November. The official dates of the congress, 18 November to 9 December, included the various field trips planned to give visiting delegates a better knowledge of a richly endowed and fascinating land.

It is gratifying to report that the Council of the Pacific Science Association announced at the final plenary session that they had unanimously accepted the joint invitation that had been extended by the National Academy of Sciences and the Bernice P. Bishop Museum to hold the Tenth Congress in Honolulu in 1961.

Great credit for the smooth operation of the congress is due the secretary-general, Charng Ratanarat, and his efficient staff and Brenda Bishop, secretary of the Pacific Science Council. The large American representation was organized by Harold J. Coolidge, executive director of the National Academy of Sciences' Pacific Science Board.

ROBERT C. MILLER
California Academy of Sciences, San Francisco

Call for Papers by AAAS Sections

Eight sections of the association will arrange sessions for contributed papers at the Washington, D.C., meeting, 26–31 December 1958. The secretaries or program chairmen to whom titles and abstracts should be sent, *not later than 30 September,* follow:

C–Chemistry. F. O. Rice, Department of Chemistry, Catholic University of America, Washington, D.C.

E–Geology and Geography. Both geology and geography, cosponsored respectively by the Geological Society of America and the Association of American Geographers, Middle Atlantic Division: Frank C. Whitmore, Jr., U.S. Geological Survey, Washington 25, D.C.

F–Zoological Sciences. (If outside the scope of the American Society of Zoologists and Society of Systematic Zoology, which are meeting with the AAAS.) Karl M. Wilbur, Department of Zoology, Duke University, Durham, N.C.

G–Botanical Sciences. Barry Commoner, Henry Shaw School of Botany, Washington University, St. Louis 5, Mo.

K–Social and Economic Sciences. Donald P. Ray, Hall of Government, George Washington University, Washington 6, D.C.

L–History and Philosophy of Science. John W. Streeter, Franklin Institute, Philadelphia 3, Pa.

Np–Pharmacy. John E. Christian, School of Pharmacy, Purdue University, Lafayette, Ind.

Q–Education. Herbert A. Smith, 205 Bailey, School of Education, University of Kansas, Lawrence, Kan.

Although the deadline is 30 September, most sections and subsequently the AAAS office, would be glad to receive titles in advance of this date.

RAYMOND L. TAYLOR
AAAS

Colloquium of College Physicists

The 20th annual Colloquium of College Physicists and the associated June Lectures will be held at the State University of Iowa, Iowa City, 18–21 June. The program will consist of lectures on

developments in contemporary physics and round-table discussions on the teaching of physics and other current problems of the profession. One evening will be devoted to the exhibit of original demonstration equipment and other teaching devices prepared by the participants. Registration is without fee.

Parapsychological Association

The formation of the Parapsychological Association, a professional group of research workers in the area of extrasensory perception and psychokinesis, has been announced. The objects of the association are to advance parapsychology as a science, to disseminate knowledge of the field, and to integrate the findings with those of other branches of science. Full membership is restricted to those with doctorate degree training or equivalent.

The founding officers are R. A. McConnell, president (Biophysics Department, University of Pittsburgh); G. R. Schmeidler, vice-president (Psychology Department, City College of New York); R. White, secretary (Parapsychology Laboratory, Duke University); R. J. Cadoret, treasurer (Duke University); and councilmen M. Anderson (Duke University), K. Osis (Parapsychology Foundation of New York), and W. G. Roll (Oxford University).

Alaskan Science Conference

The ninth Alaskan Science Conference will take place at the University of Alaska, College, Alaska, 2–5 September, under the sponsorship of the AAAS Alaska Division. The meeting will cover ten general fields of science and their application in the arctic and subarctic areas.

Titles and papers must be received by the section chairman *before 1 June*. Abstracts not exceeding 250 words should be provided by 1 July. Abstracts must be submitted for inclusion of the papers in the printed program. It is planned that abstracts or papers will be published in the Proceedings of the Ninth Alaskan Science Conference. For further information, including a list of the section chairmen, write air mail to the president and general chairman of the conference, Dr. Robert L. Rausch, President, Alaska Division, AAAS, Box 960, Anchorage, Alaska.

Biometric Conference

The fourth International Biometric Conference will be held in Ottawa from 28 August to 2 September. One day will be devoted to a symposium on biometrical genetics, and sessions are being arranged on clinical research, the interpretation of experimental results, applications of multivariate analysis, ecology and animal behavior, mathematical models in biology, the χ^2 test, and plant and animal breeding. Further details may be obtained from the local secretary, Dr. G. B. Oakland, Statistical Laboratory, Science Service Building, Department of Agriculture, Ottawa, Canada.

Society Elections

■ American Medical Writers Association: pres., Charles E. Lyght, Merck, Sharp & Dohme, Rahway, N.J.; pres.-elect, Morris Fishbein, Chicago, Ill.; past pres., Dran F. Smiley, Evanston, Ill.; sec.-treas., Harold Swanberg, 510 Maine St., Quincy, Ill. The vice presidents are Austin Smith, Chicago, Ill., and Karl A. Menninger, Topeka, Kan. The representative to the AAAS Council is Harold Swanberg.

■ Montana Academy of Sciences: pres., George W. Rollins, Social Studies Department, Eastern Montana School of Education; past pres., Philip L. Wright, Department of Zoology, Montana State University; sec.-treas., LeRoy H. Harvey, Department of Botany, Montana State University; v. pres., George H. Gloege, Eastern Montana School of Education, Billings.

■ American Meteorological Society: pres., Sverre Petterssen, University of Chicago; v. pres., Henry T. Harrison, United Air Lines, Denver, Colo.; sec., Thomas F. Malone, Travelers Insurance Companies, Hartford, Conn.; treas., Henry DeC. Ward, Eaton and Howard, Inc., Boston, Mass.

■ Institute of the Aeronautical Sciences: pres., Edward C. Wells; treas., R. Dixon Speas; director and representative to the AAAS Council, S. Paul Johnston; sec., Robert R. Dexter, 2 E. 64th St., New York 21, N.Y. The vice presidents are Neil Burgess, B. W. Chidlaw, L. Eugene Root, H. Guyford Stever.

■ American Economic Association: pres., George W. Stocking, Vanderbilt University; sec.-treas., James Washington Bell, Northwestern University, Evanston, Ill. The vice presidents are Seymour E. Harris, Harvard University and George J. Stigler, Columbia University. The representative to the AAAS Council is William S. Vickrey, Columbia University.

■ American Physical Society: pres., Jesse W. Beams, Physics Department, University of Virginia; past pres., H. D. Smyth, Princeton University; v. pres., George E. Uhlenbeck, University of Michigan; sec., Karl K. Darrow, Bell Telephone Laboratories, New York, N.Y.; treas., S. L. Quimby, Columbia University.

■ Association of Military Surgeons of the United States: pres., Charles R. Mueller; sec.-editor, Robert E. Bitner, 1726 Eye St., NW, Washington 6, D.C.; executive sec., George M. Beam. The vice presidents are H. H. Twitchell, Richard A. Kern, John W. Cronin, James P. Cooney, Irwin L. Norman, Robert C. Kimberly. The representative to the AAAS Council is Leslee W. Freeman, Indiana University.

Forthcoming Events

May

2. Engineers and Architects Conf., 5th annual, Columbus, Ohio. (H. A. Bolz, College of Engineering, Ohio State Univ., Columbus.)

2. Southern California Acad. of Sciences, annual, Los Angeles. (Miss G. Sibley, Los Angeles County Museum, Exposition Park, Los Angeles 7, Calif.)

2–3. Minnesota Acad. of Science, Bemidji. (M. R. Boudrye, 51 University Ave., St. Paul 3, Minn.)

2–3. North Carolina Academy of Science, annual, Durham. (J. A. Yarbrough, Meredith College, Raleigh, N.C.)

2–3. North Dakota Academy of Science, 50th anniversary, Fargo. (B. G. Gustafson, Box 573, University Station, Grand Forks, N.D.)

3–4. Population Assoc. of America, annual, Chicago, Ill. (D. O. Price, Inst. for

Research in Social Science, Univ. of North Carolina, Chapel Hill.)

4–7. American Federation for Clinical Research, annual, in conjunction with American Soc. for Clinical Investigation and Assoc. of American Physicians, Atlantic City, N.J. (W. W. Stead, College of Medicine, Univ. of Florida, Gainesville.)

5–6. Secondary Recovery Symp., 3rd biennial, Wichita Falls, Tex. (E. O. Kirkendall, American Inst. of Mining, Metallurgical & Petroleum Engineers, 29 W. 39 St., New York 18.)

5–7. American Geophysical Union, 39th annual, Washington, D.C. (W. E. Smith, AGU, 1515 Massachusetts Ave., NW, Washington 5.)

5–7. Microwave Theory and Techniques Symp., Stanford, Calif. (G. H. Keitel, 601 California Ave., Palo Alto, Calif.)

5–8. American Meteorological Soc., Washington, D.C. (K. C. Spengler, AMS, 3 Joy St., Boston 8, Mass.)

6–9. Optics in Metrology Colloquium, International Commission of Optics, IUPAP, Brussels, Belgium. (S. S. Ballard, Scripps Institution of Oceanography, San Diego 52, California.)

6–9. Royal Netherlands Acad. of Sciences and Letters, 105th anniversary, Amsterdam, Netherlands. (RNASL, 29 Kloveniersburgwal, Amsterdam.)

6–9. Western Joint Computer Conf., Los Angeles, Calif. (W. H. Ware, Rand Corp., 1700 Main St., Santa Monica, Calif.)

6–9. International Commission of Optics, colloquium, Brussels, Belgium. (W. D. Wright, Imperial College, South Kensington, London, S.W.7.)

7–9. Acoustical Soc. of America, annual, Washington, D.C. (W. Waterfall, 335 E. 45th St., New York 17.)

7–10. Virginia Academy of Science, annual, Roanoke. (P. M. Patterson, Dept. of Science, Hollins College, Hollins, Va.)

7–11. American Psychoanalytic Assoc., San Francisco, Calif. (J. N. McVeigh, APA, 36 W. 44 St., New York 36).

8. Association of Vitamin Chemists, Chicago, Ill. (A. E. Denton, Research Labs., Swift & Co., Chicago 9.)

8–9. Colorado-Wyoming Acad. of Science, annual, Denver, Colo. (R. G. Beidleman, Zoology Dept., Colorado College, Colorado Springs.)

8–10. Illinois State Academy of Science, 51st annual, Urbana. (R. A. Evers, Illinois Natural History Survey, Urbana.)

11–16. Social Welfare, nat. conf., Chicago, Ill. (National Conf. on Social Welfare, 22 W. Gay St., Columbus 15, Ohio.)

12–14. High Polymer Forum, 8th Canadian, Ste. Anne de Bellevue, Quebec. (M. H. Jones, Dept. of Chemistry, Ontario Research Foundation, 43 Queens Park, Toronto 5, Ont.)

12–14. Instrumental Methods of Analysis, internatl. Symp., Houston, Tex. (H. S. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh, Pa.)

12–14. Research Methods and Instrumentation Symp., 8th annual, Bethesda, Md. (J. B. Davis, National Institutes of Health, Bethesda 14.)

12–16. American Psychiatric Assoc., annual, San Francisco, Calif. (D. Blain, APA, 1785 Massachusetts Ave., NW, Washington 6.)

14. American Acad. of Arts and Sciences, Brookline, Mass. (R. W. Burhoe, 280 Newton St., Brookline 46.)

14–16. Society for Experimental Stress Analysis, Cleveland, Ohio. (W. M. Murray, P.O. Box 168, Cambridge 39, Mass.)

14–24. European Acad. of Allergy, The Hague, Netherlands. (EAA, 17 Emmalaan, Utrecht, Netherlands.)

15–16. Operations Research Soc. of America, Boston, Mass. (M. L. Ernst, Box 2176, Potomac Station, Alexandria, Va.)

15–17. Basal Ganglia Surgery for Involuntary Movement Disorders, symp., New York. (Miss D. P. Frome, Office of Public Relations, New York University-Bellevue Medical Center, 550 First Ave., New York 16.)

18–24. Sanitary Engineering, 6th Inter-American Cong., San Juan, Puerto Rico. (E. Ortega, Box 218, San Juan.)

19–21. American Trudeau Soc., 53rd annual, Philadelphia, Pa. (K. R. Boucot, Woman's Medical College, Philadelphia.)

19–23. Gas Chromatography, 2nd symp., Amsterdam, Netherlands. (G. Dijkstra, Postbox 114, Vlaardingen, Netherlands.)

20–22. Biosynthesis of Terpenes and Sterols, Ciba Foundation symp. (by invitation), London, England. (G. E. W. Wolstenholm, 41 Portland Pl., London, W.1.)

(See issue of 21 March for comprehensive list)

Equipment

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science does not assume responsibility for the accuracy of the information. A coupon for use in making inquiries concerning the items listed appears on page 830.

■ GAMMA SOURCES provide flux from 600 r/hr to 3×10^6 r/hr and higher. The source is contained in a welded steel case. Surface flux is said to be so low that the source can be used in an office or laboratory without special construction or connections. (Isotopes Specialties Co., Dept. S997)

■ DIGITAL READOUT for displaying data from digital counters presents a series of 2.5-in.-high numerals on a flat plane in straight-line sequence. The numerals are formed by a large number of high-intensity neon bulbs so that failure of individual bulbs does not falsify data. (Computer-Measurements Corp., Dept. S996)

■ PLATINUM RESISTANCE THERMOMETERS can be installed by cementing or welding on flat or curved, metallic or nonmetallic surfaces. Units are available in ranges from $-400°$ to $+1550°$F. Resistance change over the operating temperature interval is 100 ohm. Output without amplification is 5 v maximum. Accuracy of calibration is ± 1 percent of range below 1000°F. Repeatability is ± 0.2 percent of range. (Trans-Sonics Inc., Dept. S993)

■ PULSE MODULATOR produces 0- to 50-kv pulses at currents from 0 to 15 amp and at repetition rates from 10 cy to 10 kcy/sec. For pulse-group operation, triggered by an external generator, the modulator will recover and respond to pulses of varying widths occurring less than 1 μsec apart with approximate rise times 0.25 μsec and fall times 0.5 μsec. An internal trigger generator is provided for single-pulse operation. (Levinthal Electronic Products, Inc., Dept. S998)

■ DECONTAMINATING UNIT uses ultrasonic excitation to scrub radioactive particles from small articles. The tank, of stainless steel, measures 9 by 5¾ by 5¾ in. The apparatus operates on 115v a-c power and is portable. (Atomic Accessories Inc., Dept. S979)

■ AUTOMATIC ULTRASONIC WASHER for surgical instruments and laboratory glassware operates unattended except for loading. Filling, washing, draining, and rinsing are automatically sequenced. Up to 100 surgical instruments are accommodated. (American Hospital Supply Corp., Dept. S995)

■ NEBULIZER generates aerosol particles of size 0.5 to 3.0 μ at flow rates as low as 3 lit/min and up to 15 lit/min. A whistle warns of obstruction of the outlet tubing throughout the flow range. (Air Reduction Co., Inc., Dept. S970)

JOSHUA STERN
National Bureau of Standards

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